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**AVIONICS EVALUATION PROGRAM:
MULTIPLE AIRCRAFT, MULTIPLE SORTIES,
AND COST ACCUMULATION**

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An updated version of the air-to-ground Avionics Evaluation Program (AEP) has been developed. The AEP provides a mechanism for assessing the mission impact of varying avionics hardware configurations. This program is a Monte Carlo simulation of a flight of aircraft (up to four) through a specified number of days of operation. Functions considered include ground maintenance, communication, navigation, refueling, target acquisition, and weapon delivery. The present effort incorporated imperfect equipment monitoring, multiple aircraft, multiple sorties, and cost accumulation. The previous framework for consideration of hardware reliability and backup modes has been retained. The interactive graphics processor has been updated. A more convenient technique for accessing hardware and function data has been incorporated. More flexibility has been added to the output processor to allow selective display of simulation results.

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FOREWORD

This is the final report on work conducted to develop an updated version of the air-to-ground Avionics Evaluation Program (AEP) by Battelle's Columbus Laboratories, 505 King Avenue, Columbus, Ohio 43204. This work was performed for the U. S. Air Force Avionics Laboratory, Wright-Patterson Air Force Base, Ohio 45433. Information in this report covers work conducted under Contract F33615-76-C-1069, Project 2003/09/05. The Air Force Program Monitor is Captain Ken Almquist (AFAL/AAA), Systems Avionics Division. Research on this final report was conducted from January 15, 1976, through June 30, 1976. No copyrighted material is included. This report was submitted by the author on August 2, 1976.

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I. INTRODUCTION

This report documents the results of an effort to update the Avionics Evaluation Program (AEP). The original AEP (described in Reference 1) was developed to provide the Air Force Avionics Laboratory with an efficient tool for conducting in-house analyses of current and postulated weapon system concepts performing air-to-ground missions in a wide spectrum of operational environments. In January, 1973, an interactive graphics capability was added to provide much more efficient use of the program. The unique help features an on-line user's manual which has allowed use of the program with a minimum of training.

The purpose of the present effort was to develop an improved version of the AEP and to incorporate imperfect equipment monitoring, multiple aircraft, multiple sorties, and cost accumulation. The effort started in January, 1976, with a review of existing logistics models and cost models. Planned program development was reviewed and approved in March, 1976.

This report contains the following elements:

- (1) A description of the AEP program structure
- (2) A detailed description of the individual mission functions
- (3) A description of updates to the interactive graphics processor

II. SUMMARY

An updated version of the AEP has been developed. This program is a Monte Carlo simulation of a flight of aircraft (up to four) through a specified number of days of operation. Functions considered include ground maintenance, communication, navigation, refueling, target acquisition, and weapon delivery. Emphasis was placed on the development of ground service requirements, target acquisition, weapon delivery, and cost accumulation. The previous framework for consideration of hardware reliability and backup modes has been retained. The program operates as follows:

- (1) The user provides data which: (a) defines the flight profile, (b) lists the hardware makeup (all aircraft are identically equipped) and (c) defines the functions and associated performance for the simulation.
- (2) The program makes a deterministic evaluation of the mission. As part of this evaluation, the vehicle equations of motion are integrated to determine the nominal time history of the flight. The aircraft states are stored as a function of time for use during the Monte Carlo evaluation.
- (3) A Monte Carlo simulation is conducted. A single Monte Carlo trial is represented by simulating the scheduled flight operations for a specific number of days. The events that occur during a mission depend on random draws from probability distributions described by function performance data and hardware reliability. Numerous trials are simulated to estimate: (a) mission success, (b) mission aborts, (c) aircraft losses, and (d) mission cost.

The interactive graphics processor has been updated. A new and more easily used technique for accessing hardware and function data has been incorporated. Additional features for displaying output results have also been added.

III. PROGRAM STRUCTURE

The objective in developing a revised version of the air-to-ground AEP was to incorporate the following items:

- (1) Imperfect Equipment Monitoring
- (2) Multiple Sortie Capability
- (3) Multiple Aircraft Capability
- (4) Cost Accumulation

The AEP provides a mechanism for assessing the mission impact of varying avionics hardware configurations (navigation, target acquisition, weapon delivery, etc.). This includes hardware reliability as well as performance. In addition, the multiple sortie feature provides a measure of maintainability with respect to preparing the aircraft for the next flight. The program allows users to obtain a quantitative (rather than qualitative) view of the importance and interaction of the hardware characteristics. It can also provide a common framework through which various Air Force and contractor agencies can effectively communicate requirements, portray results, and make cost-effective judgements.

The AEP considers a flight of up to four aircraft for a given number of consecutive days. Figure 1 shows a flow diagram of the daily operations. As the mission simulation progresses, it is influenced by hardware failures, aircraft maintenance, ordnance loading, navigation, target acquisition, weapon capabilities, and enemy defenses. At the conclusion of the specified simulation period, costs are accumulated for several areas of interest.

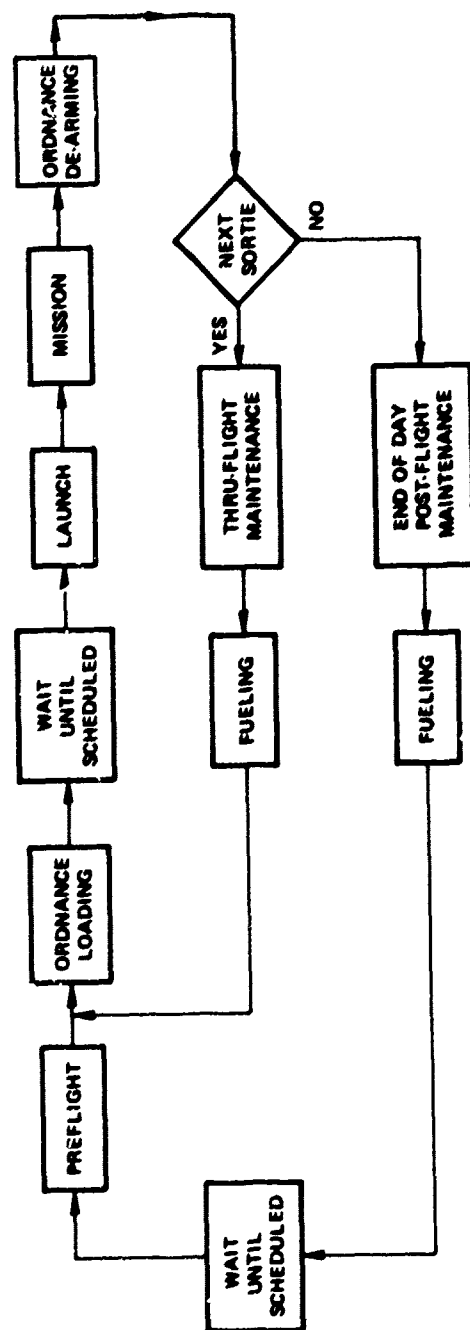


FIGURE 1. GROUND SUPPORT FUNCTIONS

General Description

The AEP evaluates the operation of a flight of up to four aircraft over a given period of days. The "system" is described by the vehicle hardware makeup, flight profile, and functions/subfunctions. All aircraft must be identically equipped. Thus, hardware data are given for only one aircraft and the program assumes the same equipment specifications for the remaining aircraft.

One important extension of the previous version's capability is to allow several subfunctions under a given function to operate simultaneously. For example, the user might turn on both display and visual target acquisition. The function/subfunction hierarchy is described in detail in a later section.

The updated AEP mechanization provides a more flexible interaction between functions. For example, the sequencing from one function to another can occur automatically as the result of previous events, as well as through specific control by the user. Sequencing through the simulation is controlled by an executive event-time routine. In general, the subfunctions calculate when an event will occur and what happens when the time of that event is reached. When a subfunction computes an event-time and type, the event is placed in proper time sequence in a table of events. When the time of the event is reached, the executive routine calls the routine indicated by the event type. This concept of event processing is described in more detail under "Monte Carlo Evaluation" on Page 15 .

Aircraft Equipment Description

As part of the input data, the user must describe the equipment list that makes up an aircraft. The user usually has complete flexibility to aggregate or disaggregate actual "black boxes" into equipment elements. Two terms, section and candidate, used in the description of hardware, are defined here.

A section is a general category of hardware such as fire control system or communications. In general, the first two digits of the standard five digit Air Force Work Unit Code (WUC) defines a section.

A candidate is a specific hardware item within a given section. For example, candidates for an inertial navigation system might be LN-15, LN-12, INS-16, or some other specific system.

Table 1 lists the standard data items associated with every section. Several sections have additional data items which reflect performance data unique to those sections. When a user defines a candidate for a section, values must be entered for all data items associated with that section. It should be noted that performance data items are not associated with sections unless performance characteristics are always required from that particular section. For example, the program always requires aerodynamic data associated with the airframe and thrust data associated with the propulsion system.

TABLE 1. STANDARD EQUIPMENT DATA ITEMS

1.	MTBF - True mean time between failures based on flight hours
2.	MTBMA - Mean time between unscheduled maintenance actions
3.	OFR - Operational hours per flight hour
4.	P_v - Vulnerability
5.	N_R - Number of redundant boxes
6.	MTTR - Mean time to repair
7.	P_R - Probability the box will be replaced
8.	P_A - Probability replacement box is available
9.	P_u - Probability of undetected failure
10.	P_F - Probability of false failure
11.	A_c - Acquisition cost
12.	UM_c - Cost per unscheduled maintenance action

Functions, Subfunctions, Modes and States

The concept of functions, subfunctions, modes, and states used in the AEP is fundamental to the evaluation procedures. Functions are the operations or actions performed during the simulation. Subfunctions represent alternative options for performing a particular function. Table 2 shows a list of functions and associated subfunctions with their data requirements. A description of each of these is contained in the "Description of Individual Functions".

TABLE 2 . FUNCTION/SUBFUNCTION DATA REQUIREMENTS

-
1. Scheduled Maintenance
 - 1.1 Preflight
 - a. Mean Duration
 - b. Standard Deviation
 - c. Equipment List
 - 1.2 Thrufight
 - a. Mean Duration
 - b. Standard Deviation
 - c. Equipment List
 - 1.3 Postflight
 - a. Mean Duration
 - b. Standard Deviation
 - c. Equipment List
 2. Ordnance
 - 2.1 General Purpose Munitions
 - a. Number of Weapons Carried
 - b. Mean Loading + Arming Time Per Weapon
 - c. Standard Deviation
 - d. Mean Dearming & Arming Time Per Weapon
 - e. Standard Deviation
 - 2.2 Rockets
 - a. Number of Weapons Carried
 - b. Mean Loading & Arming Time Per Weapon
 - c. Standard Deviation
 - d. Mean Dearming & Arming Time Per Weapon
 - e. Standard Deviation
-

TABLE 2 . FUNCTION/SUBFUNCTION DATA REQUIREMENTS (Continued)

-
- 3. Fueling
 - 3.1 Fuel Loading
 - a. Fueling Rate
 - 3.2 Fuel Usage
 - a. Bogie Fuel Level
 - 3.3 Refueling
 - a. Minimum Hookup Time
 - b. Maximum Hookup Time
 - c. Refueling Rate
 - d. Number of Aircraft Refueled Simultaneously
 - 4. Flight
 - 4.1 Launch
 - a. Mean Wait Time
 - b. Standard Deviation
 - 4.2 Inflight Aircraft Abort
 - a. Required Equipment
 - b. Required Aircraft
 - 4.3 Mission Abort
 - a. Required Aircraft
 - 4.4 Loss of Aircraft
 - a. Required Equipment
 - 4.5 Landing
 - 5. Mission
 - 5.1 Schedule
 - a. Earliest Time to Begin Preflight
 - b. Earliest Time to Begin Launch
 - c. Minimum Time Until Next Sortie
 - d. Latest Time to Launch Sortie
 - e. Maximum Delay Before Cancel
 - f. Number of Days to Simulate
-

TABLE 2 . FUNCTION/SUBFUNCTION DATA REQUIREMENTS (Continued)

5.2 Cost Accumulation

- a. Number of Aircraft per Squadron
- b. Fuel Cost
- c. Per Flight Cost
- d. Per Unit of Flight Time Cost
- e. Flight Crew Size
- f. Flight Crew Cost
- g. Ground Crew Size
- h. Ground Crew Cost
- i. Munitions Crew Size
- j. Munitions Crew Cost
- k. Command Staff Size
- l. Command Staff Cost
- m. Number of Additional Personnel
- n. Additional Personnel Cost
- o. Investment Peculiar to System
- p. Amortization Period

6. Formation

6.1 Nominal Flight

- a. Position of Aircraft 2 Relative to Aircraft 1
- b. Position of Aircraft 3 Relative to Aircraft 1
- c. Position of Aircraft 4 Relative to Aircraft 1

7. Navigation

7.1 Radio-Aided Navigation

- a. Fixed Position Error
- b. Correlation Time Constant

7.2 Self-Contained Navigation

- a. Per Unit Time Error Growth Rate
 - b. Correlation Time Constant
-

TABLE 2. FUNCTION/SUBFUNCTION DATA REQUIREMENTS (Continued)

-
- 8. Navigation Update
 - 8.1 Automatic Navigation Update
 - a. Depression Angle to Center of Field of View
 - b. Horizontal Width of Field of View
 - c. Checkpoint Location CEP
 - d. Probability of Detection/Recognition
 - e. Accuracy of Update
 - 8.2 Radar Navigation Update
 - a. Depression Angle to Center of Field of View
 - b. Horizontal Width of Field of View
 - c. Checkpoint Location CEP
 - d. Probability of Detection/Recognition
 - e. Accuracy of Update
 - 8.3 Visual Navigation Update
 - a. Depression Angle to Center of Field of View
 - b. Horizontal Width of Field of View
 - c. Checkpoint Location CEP
 - d. Probability of Detection/Recognition
 - e. Accuracy of Update
 - 9. Communications
 - 9.1 Interflight
 - 9.2 External
 - 10. Survivability
 - 10.1-10.5
 - Survivability Subfunctions
 - a. Constant Probability of Hit
 - b. Per Unit Time Probability of Hit
 - c. Probability of Aircraft Kill
-

TABLE 2. FUNCTION/SUBFUNCTION DATA REQUIREMENTS (Continued)

11. Target Acquisition

11.1 Display Acquisition

- a. Horizontal Width of Sensor Field of View
- b. Side Look Angle for Each Aircraft
- c. Table of Depression Angles
- d. Cumulative Probability of Detection vs. Depression Angle

11.2 Visual Acquisition

- a. Horizontal Width of Sensor Field of View
- b. Side Look Angle for Each Aircraft
- c. Table of Depression Angles
- d. Cumulative Probability of Detection vs. Depression Angle

12. Weapon Delivery

12.1 Manual Weapon Delivery

- a. Weapon Release Distance
- b. Set-Up Time
- c. Aiming CEP
- d. Primary Kill Radius
- e. Secondary Kill Radius
- f. Ordnance Subfunction Type
- g. Number Dropped per Pass
- h. Targets

12.2 Automatic Weapon Delivery

- a. Weapon Release Distance
 - b. Set-Up Time
 - c. Aiming CEP
 - d. Primary Kill Radius
 - e. Secondary Kill Radius
 - f. Ordnance Subfunction Type
 - g. Number Dropped per Pass
 - h. Targets
-

TABLE 2 . FUNCTION/SUBFUNCTION DATA REQUIREMENTS (Continued)

13. Target

13.1-13.5

Target Subfunctions

- a. Number of Attack Passes**
 - b. X Location Uncertainty**
 - c. Y Location Uncertainty**
-
-

Several operating modes are possible for each subfunction (primary and backup operating modes). The concept of modes is straightforward for a one aircraft simulation. In that case, there is a suite of hardware and performance data associated with each mode defined for a subfunction. Presumably, a user sets up a problem such that the first mode represents the best performance and subsequent modes represent degraded performance. The introduction of multiple aircraft complicates the problem as the modes must then apply to the complete flight. The user defines mode regression criteria using subfunction states. A subfunction state defines the equipment status for each aircraft for that subfunction. Associated with each state is a suite of hardware selected from the available equipment items. State 1 represents the primary equipment suite and subsequent states represent progressively degraded hardware status. Based on the definition of these states, Boolean AND/OR logic is used to define the criteria for each mode. For example, mode 1 of a given subfunction may require either aircraft A or B in the primary state or both in a secondary state. This would be represented as: $A1 + B1 + A2 \cdot B2$. If none of these requirements were satisfied because of equipment failures; mode regression would occur. Figure 2 is a diagram of the function/subfunction/mode/state hierarchy. Note that hardware selections for a single aircraft are made to define states for each aircraft and that performance data are entered to define each mode. Although this system of specifying aircraft status and performance is complicated, there is no apparent simplification which will not severely limit user flexibility.

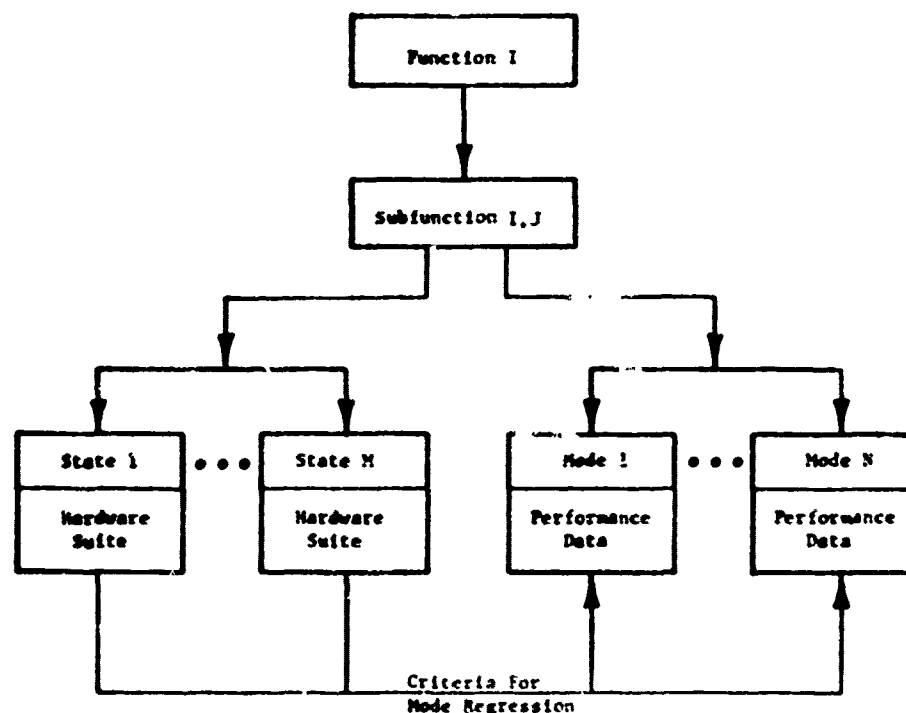


FIGURE 2. FUNCTION/SUBFUNCTION/MODE/STATE HIERARCHY

Flight Profile

Flight path definition is essentially unchanged from the original AEP. Users specify waypoints at arbitrary locations along the flight path. Waypoints only need to be specified where some change (heading, velocity, functions, etc.) occurs. The previously required mission phases and defense zones are no longer used. Both are incorporated within the framework of the functions and subfunctions.

Nominal Simulation

The mission simulation is separated into two parts; a nominal or deterministic evaluation and a Monte Carlo simulation. The purpose of the nominal simulation is to establish the aircraft time history in the absence of uncertainties. The aircraft equations of motion are integrated during the nominal simulation and the resultant aircraft state vector is stored for use in the Monte Carlo. In addition, any deterministic calculations required by the functions are performed with the results saved for the Monte Carlo. At present, only the target acquisition, weapon delivery, and formation functions are used during the nominal simulation.

Cost Accumulation

The inclusion of the ground turnaround process in the AEP is a continued expansion of the measures of effectiveness. This extension, however, must consider the availability and application of many types of resources other than the aircraft and its internal equipment. These sources include personnel, spares, support equipment and fuel. In these days of austere funding, these resources are not abundant. Therefore, the allocation of these resources to specific aircraft systems and mission objectives must be analyzed thoroughly. The cost accumulator is aimed at quantifying these resources in terms of dollar costs per flight.

In addition to acquisition costs of the aircraft and internal systems, the following types of costs are considered:

- (1) Maintenance costs for repair of failures and other maintenance actions
- (2) Replacement costs for systems lost

(3) Operations costs for

- (a) consummables
- (b) personnel
- (c) amortization of investments in support equipment, facilities, etc.

Monte Carlo Evaluation

The Monte Carlo simulation sequences through the daily operations, as shown in Figure 1, for a given number of days. Random numbers are drawn from the uncertain event distributions given by the user to determine actual occurrences during the evaluation. Statistics describing the simulation results are accumulated for examination by the user.

The Monte Carlo executive routine executes a sequence of events stored in chronological order. In general, the events are keyed by an integer triplet (i,j,k), where i represents a level 1 event, j a level 2 event, and k a level 3 event. Table 3 is a listing of the events in the current version of the AEP. Only two events occur at repetitive fixed times:

(1) Schedule each day, event (5,1,1) at $t = 0:00$ and (2) End of day, event (24,0,0) at $t = 24:00$. All other events occur based on the occurrence of previous events. Table 4 shows a hypothetical set of events for one day with two aircraft. At the beginning of the simulation, the event table contains only the two events (5,1,1) at 0:00 and (24,0,0) at 24:00. The remaining events are created and entered into the table as the simulation progresses. Thus, the call to schedule creates the begin preflight event (1,1,1) at $t=6:00$. The preflight subfunction creates the ordnance calls, which create calls back to preflight to signify the completion of ordnance loading. After both aircraft are loaded, the schedule routine is called to determine the launch time. Similarly, all of the remaining events are created and entered into the table.

One major modification in the new AEP is the simulation of equipment malfunctions. To evaluate the impact of equipment monitoring, both undetected and false failures are accounted for. Figure 3 shows a transition diagram of the new failure model. State 1 is a fully operational ready status. All unscheduled maintenance actions fall into 3 categories.

State 2--Pilot complaint, equipment calibration, etc.

State 3--False failure indication.

State 4--True failure indication.

TABLE 3. MONTE CARLO EVENT INDICES

LEVEL 1	LEVEL 2	LEVEL 3
1. Call Scheduled Maintenance	1 Call Preflight	1. Initial entry, set end of preflight 20+1. Aircraft I finishes preflight, check for additional failures 30+1. Aircraft I not finished with post-flight, check again later
	2 Call Thruflight	1. Initial entry, set end of thru-flight 3. Ground abort of mission 3+1. Aircraft I finishes thruflight, check for additional failures
	3 Call Postflight	1. Initial entry, set end of postflight 20+1. Aircraft I finishes postflight, check for additional failures
2. Call Ordnance	1 Call General Purpose Munitions	10+1. Aircraft I loading, calculate total loading time 20+1. Aircraft I dearming for maintenance, calculate total dearming time 30+1. Aircraft I has expended all ordnance
	2 Call Rockets	10+1. Aircraft I loading, calculate total loading time 20+1. Aircraft I dearming for maintenance, calculate total dearming time 30+1. Aircraft I has expended all ordnance

TABLE 3. MONTE CARLO EVENT INDICES (Continued)

LEVEL 1	LEVEL 2	LEVEL 3
2. Call Ordnance (Continued)	3 Call Guided Weapons 4 Initiate Loading 5 Terminate Loading 6 Initiate Dearing 7 Terminate Dearing	10+I. Aircraft I loading, calculate total loading time 20+I. Aircraft I dearming for maintenance, calculate total dearming time 30+I. Aircraft I has expended all ordnance
3. Call Fueling	1 Call Fuel Loading	1. Loading fuel, calculate fuel loading time
	2 Call Fuel Usage	1. Check fuel level against bingo fuel level
	3 Call Air Refueling	1. Initial entry, calculate hookup time for each aircraft 2. Hookup Aircraft 1 3. Hookup Aircraft 2 4. Hookup Aircraft 3. 5. Hookup Aircraft 4 6. Hookup slot released
4. Call Flight	1 Call Launch	1. Initial entry, calculate launch time 2. Takeoff, turn flight subfunctions on
	5 Call Landing	1. Landing, turn flight subfunctions off
5. Call Mission	1 Call Schedule	1. Beginning of day, set preflight and scheduled launch time 2. Preflight/thruflight finished, check for delay or launch 3. End of sortie, check for next sortie or end of day
	2 Call Cost Accumulation	1. Calculate total simulated cost

TABLE 3. MONTE CARLO EVENT INDICES (Continued)

LEVEL 1	LEVEL 2	LEVEL 3
7. Call Navigation	1 Call Radio-Aided Navigation	1. Initial entry, calculate current navigation error 100. Mode change, calculate current navigation error
	2 Call Self-Contained Navigation	1. Initial entry, calculate current navigation error 100. Mode change, calculate current navigation error
	1 Call Automatic Navigation Update	1. Calculate sensor field of view; calculate navigation update error
	2 Call Radar Navigation Update	1. Calculate sensor field of view; calculate navigation update error
8. Call Navigation Update	3 Call Visual Navigation Update	1. Calculate sensor field of view; calculate navigation update error
	1-5 Call Survivability Subfunctions	1. Initial entry, calculate time of hit for each aircraft I+1. Hit processor, assess damage to Aircraft I 100. Mode change remove old hit events; calculate new hit events
	1 Call Display Acquisition	1. Initial entry, calculate detection times 2. Target detected, calculate time of detection
11. Call target acquisition	2 Call Visual Acquisition	100. Mode change, remove old detection times 1. Initial entry, calculate detection times 2. Target detected, calculates time of detection
		100. Mode change, remove old detection times

TABLE 3. MONTE CARLO EVENT INDICES (Continued)

LEVEL 1	LEVEL 2	LEVEL 3
12. Call Weapon Delivery	1 Call Manual Weapon Delivery	1. Initialization 2. Check equipment status 3. Check for weapon release ranges 4. Ready for attack, check for undetected failures 5. Attack target 100. Mode change, find usable mode
	2 Call Automatic Weapon Delivery	1. Initialization 2. Check equipment status 3. Check for weapon release ranges 4. Ready for attack, check for undetected failures 6. Attack target 100. Mode change, find usable mode
13. Call Target	1-5 Get Target (1-5) Data	
21. Get Aircraft States at Next Waypoint		
23. Create next Failure Event		
24. End of Day		
25. Function on/off	1-20 Function Number (1-20)	-1. Turn function off 1-f. Turn subfunction (1-9) on
26. Test Print		
27. Equipment Failure	10J+I Item J on Aircraft I failed	
30. Accumulate costs		

TABLE 4. MONTE CARLO EVENT HISTORY

Time	Event Indices	Description
0:00	5,1,1	Begin day, call schedule
6:00	1,1,1	Begin preflight
8:15	2,4,12	Begin ordnance loading for A/C 2
8:20	2,4,11	Begin ordnance loading for A/C 1
8:30	1,1,22	A/C 2 loaded
8:40	1,1,21	A/C 1 loaded
8:40	5,1,2	All A/C ready, schedule launch
9:00	4,1,1	Scheduled launch
9:10	4,1,2	Take-off
10:30	4,5,1	Landing
10:30	5,1,3	Check schedule for another sortie
10:30	1,2,1	Begin thru-flight maintenance
12:30	2,6,12	Dearm A/C 1
12:35	2,6,22	Dearm A/C 2
12:40	3,3,12	Fuel A/C 1
12:50	3,3,22	Fuel A/C 2
13:00	2,4,11	Begin ordnance loading A/C 1
13:05	2,4,12	Begin ordnance loading A/C 2
13:15	1,2,4	A/C 1 loaded
13:20	1,2,5	A/C 2 Loaded
13:20	5,1,2	Schedule launch
13:20	4,1,1	Late launch, scheduled for 13:00
13:30	4,1,2	Take-off
15:00	4,5,1	Landing
15:00	5,1,3	Check schedule
15:00	1,3,1	End of day's sorties, begin post flight

TABLE 4. MONTE CARLO EVENT HISTORY (Continued)

Time	Event Indices	Description
18:30	2,6,23	Unload ordnance on A/C 2
18:45	3,1,23	Fuel A/C 2
19:00	2,6,13	Unload ordnance on A/C 1
19:05	1,3,22	A/C 2 finished fuel loading
19:20	3,1,23	Fuel A/C 1
19:35	1,3,21	A/C 1 finished fuel loading
24:00	24,0,0	End of day

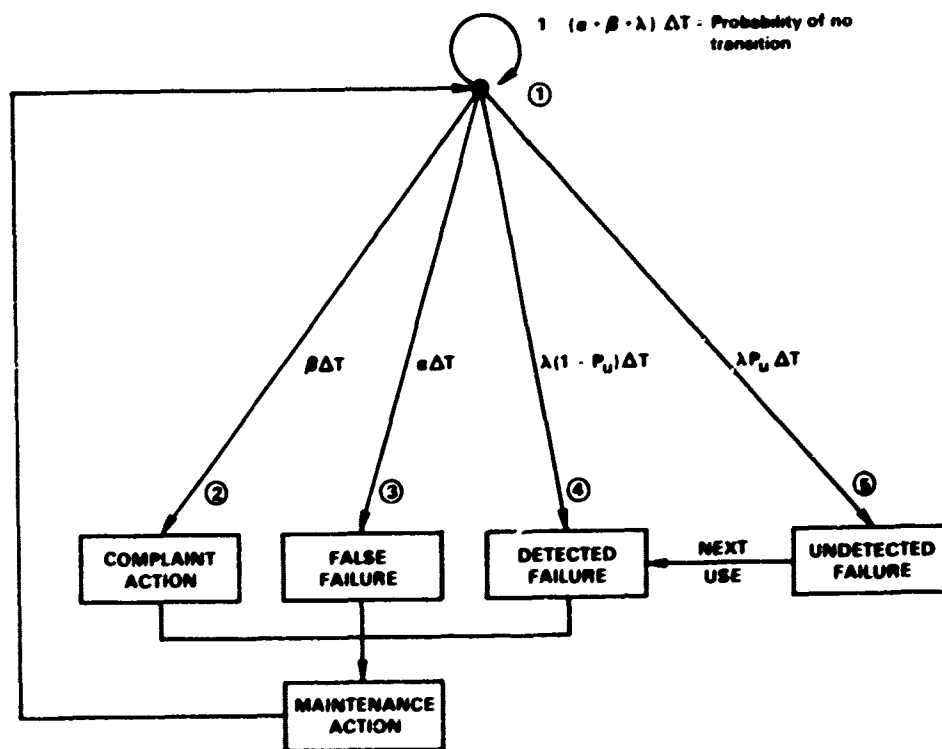


FIGURE 3. FAILURE MODEL

In addition, true failures may be undetected (State 5) until the next attempted use of that item. The incremental transition probabilities for states 2 thru 5 are:

$$P_2 = \beta \Delta T$$

$$P_3 = \alpha \Delta T$$

$$P_4 = \lambda (1 - P_u) \Delta T$$

$$P_5 = \lambda P_u \Delta T$$

where

α = False failure rate,

β = Non-failure (calibration, complaint, etc.) rate,

λ = True failure rate,

P_u = Probability of undetected true failure .

The rates α , β , and λ determine the total maintenance actions, so that

$$MTBMA = \frac{1}{\alpha + \beta + \lambda} \quad (1)$$

and the probability of being in State 1 is

$$P_1(t) = e^{-t/MTBMA} \quad (2)$$

Given that a transition from State 1 occurs, the following conditional probabilities define the transition:

$$P_2 = \frac{\beta}{\alpha + \beta + \lambda} \quad (3)$$

$$P_3 = \frac{\alpha}{\alpha + \beta + \lambda} \quad , \quad (4)$$

$$P_4 = (1 - P_u) \frac{\lambda}{\alpha + \beta + \lambda} \quad , \quad (5)$$

and

$$P_5 = P_u \frac{\lambda}{\alpha + \beta + \lambda} \quad . \quad (6)$$

State 3 is the false failure state and λ is the true failure rate, thus

$$\lambda = \frac{1}{MTBF} \quad , \quad (7)$$

$$\alpha = P_F/MTBMA \quad , \quad (8)$$

and

$$\beta = \frac{1}{MTBMA} - \lambda - \alpha \quad . \quad (9)$$

Since β must be non-negative,

$$\frac{1}{\text{MTBMA}} \geq \lambda + \alpha \quad (10)$$

or

$$\text{MTBMA} \leq (1 - P_F) \text{MTBF} . \quad (11)$$

The three data values MTBF, MTBMA, and P_F are not completely independent. If the user input values do not satisfy the above relationship, the MTBMA is adjusted to satisfy the inequality.

Checking of subfunction status occurs when the operation of an equipment item is lost. Each transition to State 3 or 4 will cause an immediate decrement in the number of redundant boxes carried. Transition to State 5 will not be counted until the next use. When all redundant boxes have failed, subfunction state regression will occur. Transition to State 2 will not be interpreted as losing that item, but will require ground service after the sortie.

To reduce the total number of failure events (e.g. 4 aircraft, each with 20 equipment items, means 80 events must be tracked) it is assumed that the equipment items on each aircraft are connected in series. Then the probability of failure (leaving state 1) in time t is

$$P_f = 1 - e^{-\lambda_T t} , \quad (12)$$

where

$$\lambda_T = \sum_{i=1}^n \lambda_i = \text{total failure rate per flight hour}$$

$$\lambda_i = \text{failure rate of } i\text{'th equipment item.}$$

Thus, P_f defines the probability distribution of the time to failure of any item. Given that a failure occurs at time = t , the specific item that failed is determined by the probabilities

$$P_i = \frac{\lambda_i}{\lambda_T} . \quad (13)$$

Note that, since a failure has occurred, the sum on P_i equals 1. Since P_f defines a failure time based on flight hours, the true failure time is

$$t^* = K_i t, \quad (14)$$

where

K_i = operating hours per flight hour for the i 'th item

In general, $K_i > 1$, thus failures may occur both airborne and on the ground, even though t is generated only during actual flight time. When a failure (transition from state 1) occurs, the probabilities P_2 - P_5 defined previously, are used to determine which state is reached. In addition, the total failure rate is reduced by the rate of the failed item and no further transitions occur for that item until it is restored to state 1 by some maintenance action.

Monte Carlo Output

The results of the simulation are stored as a permanent file and accessed via the AEP interactive program. The output is composed of statistics describing random variables, number of occurrences of random events, and function/subfunction utilization. The user can selectively examine the output with different levels of detail. A detailed description of the output display is given under "Interactive Processor".

Appendix A shows the input and full output for a sample execution of the AEP. The simulation consisted of 25 Monte Carlo trials, using two aircraft for one week. The data and results shown are for illustrative purposes only, and should not be interpreted as an evaluation of any real system.

IV. DESCRIPTION OF INDIVIDUAL FUNCTIONS

Table 2 listed the AEP functions and associated subfunctions. Most of the functions have computations only in the Monte Carlo portion of the program. When a function or subfunction creates an event, the following information is required by the executive routine:

- (1) Level 1 event type (generally the number of the function which will process the event)
- (2) Level 2 event type (generally the number of the associated subfunction)
- (3) Level 3 event type
- (4) Time of event

Table 3 showed all of the current events in the AEP.

The general format of the functions consists of seven subroutines defined as follows:

- (1) RSETXX - routine to retrieve the data associated with the current mode of subfunction under function XX
- (2) FUNXX - routine to perform calculations for function XX during the nominal evaluation
- (3) SUBX.Y - routine for each subfunction Y under function XX to perform nominal calculations
- (4) MCFNXX - routine to perform Monte Carlo calculations for function XX
- (5) MSBXXY - routine for each subfunction Y under function XX for Monte Carlo calculations
- (6) ABRTXX - routine containing logic for aborting an aircraft if no equipment states are available for function XX
- (7) FABTXX - routine containing logic for aborting sortie if no modes remain for function XX.

In general, each subfunction creates events for any calculations or decisions required by that subfunction. However, the executive routine always forces the following subfunction events for any required action by the subfunctions:

- (1) Event (I,J,1) when Function I, Subfunction J is turned on
- (2) Event (I,J,100) when a mode regression for Function I, Subfunction J occurs
- (3) Events (I_i,J_j,101) for all Functions I; Subfunctions J; that are active, whenever some aircraft in the flight aborts or is lost

Some of the functions are turned on/off by user input with the flight profile definition, while others are controlled internally by the program. Table 5 lists the type of control for each function. Following is a description of each function and subfunction.

TABLE 5. LIST OF INITIAL FUNCTION CALLS

Function	Control
1. Scheduled Maintenance	Internal
2. Ordnance	Internal
3. Fuel	
3-1. Loading	Internal
3-2. Usage	User turn on
3-3. Refueling	User turn on
4. Flight	Internal
5. Schedule	Internal
6. Formation	User turn on
7. Navigation	User turn on
8. Navigation Update	User turn on
9. Communication	User turn on
10. Survivability	User turn on
11. Target Acquisition	User turn on
12. Weapon Delivery	a. Turned on and activated internally by target detection

TABLE 5. LIST OF INITIAL FUNCTION CALLS (Continued)

Function	Control
12. Weapon Delivery (Continued)	or b. User turn on prior to target detection, then activated at detection
13. Target	Internal

Scheduled Maintenance

The scheduled maintenance function provides an assessment of the time involved to keep the aircraft ready for flight. Three sub-functions are provided to account for Preflight (beginning of day), thru-flight (between sorties), and postflight (end of day) maintenance requirements. Data required to describe the ground maintenance are: mean duration, standard deviation, and equipment check list. Air Force data sources⁽³⁾ indicate that repair times tend to follow a log-normal distribution. Hence, the random service time is drawn from a log-normal distribution defined by the input parameters. Figure 4 shows the repair logic flow. It is assumed that any item in the check list would require some form of inspection, thus those items will transition from an undetected to a detected failure state (refer also to Figure 3). In addition, it is assumed that the repair of items in the checklist occurs in parallel with the maintenance time, and that repair of other items is in series. Thus, the total maintenance time is given by:

$$T_{\text{maint}} = \max(T_s, t_i) + \sum t_j \quad (15)$$

where

T_s = scheduled time

t_i = maximum repair time of checklist items

t_j = repair time of item not in list

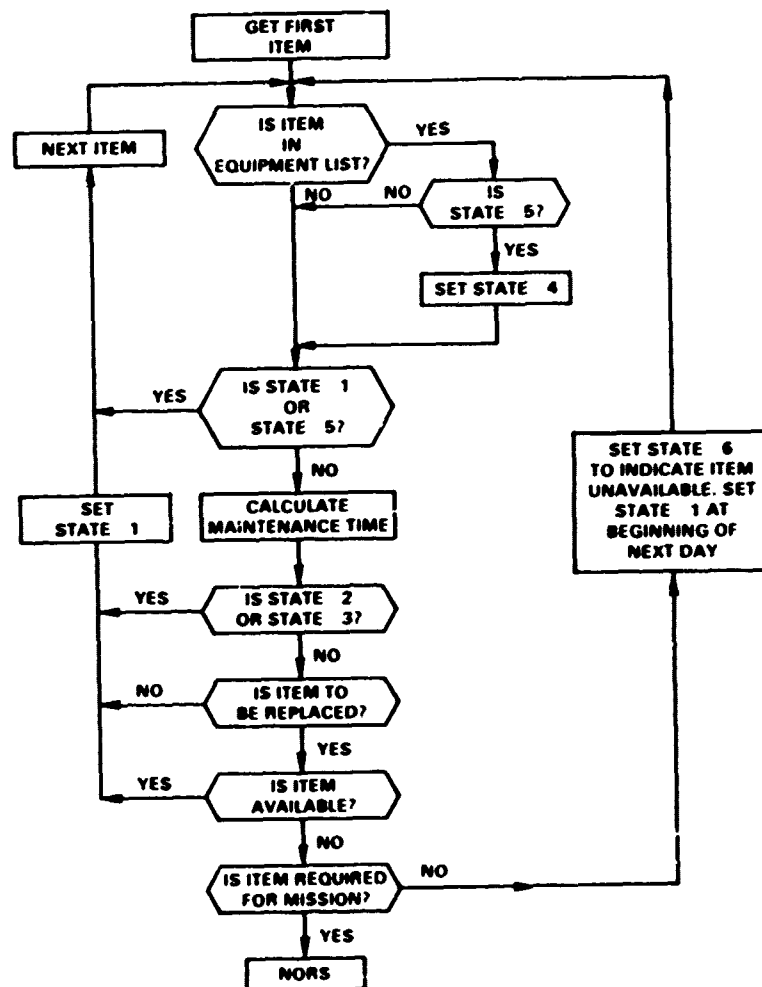


FIGURE 4. SCHEDULED MAINTENANCE

There are no nominal calculations, aircraft aborts, or mission aborts associated with this function. The Monte Carlo Routine (MCFN01) transfers control to the appropriate subfunction.

Preflight Subfunction

Figure 5 shows the logic flow for this subfunction. The preflight routine (MSB011) sequences each aircraft to ordnance loading at the completion of the maintenance interval. If one or more aircraft becomes NORS, the remainder of the day is cancelled, otherwise control passes to the schedule routine when all aircraft are ready.

Thru-flight Subfunction

Figure 6 shows the logic flow for this subfunction. The thru-flight routine (MSB012) sequences each aircraft to ordnance de-arming at the completion of maintenance. In reality, de-arming would occur prior to ground service. However, for convenience in programming and since the total time interval is the same, thru-flight and de-arming times are reversed. As with the preflight routine, a NORS state cancels the day, otherwise the schedule routine is called after all aircraft are ready.

Postflight Subfunction

Figure 7 shows the logic flow for this subfunction. The postflight routine (MSB013) sequences each aircraft to ordnance de-arming (same reason as for thru-flight) at the completion of maintenance. Since postflight occurs at the end of the day's sorties, a NORS state has no impact. One additional difference for postflight is that all redundant items are repaired. Preflight or thru-flight maintenance require only that one or more of a redundant set be operational.

Ordnance Function

The ordnance function calculates the time required to load and aim the ordnance prior to each sortie, and also calculates the time required to unload and dearm the ordnance at the end of each sortie. There are two ordnance subfunctions: general purpose munitions and rockets. The logic within the subfunctions is identical. The difference lies in the distributions which describe the loading and unloading times of the different munitions. Each type of munition would normally have its own distribution of loading and unloading terms.

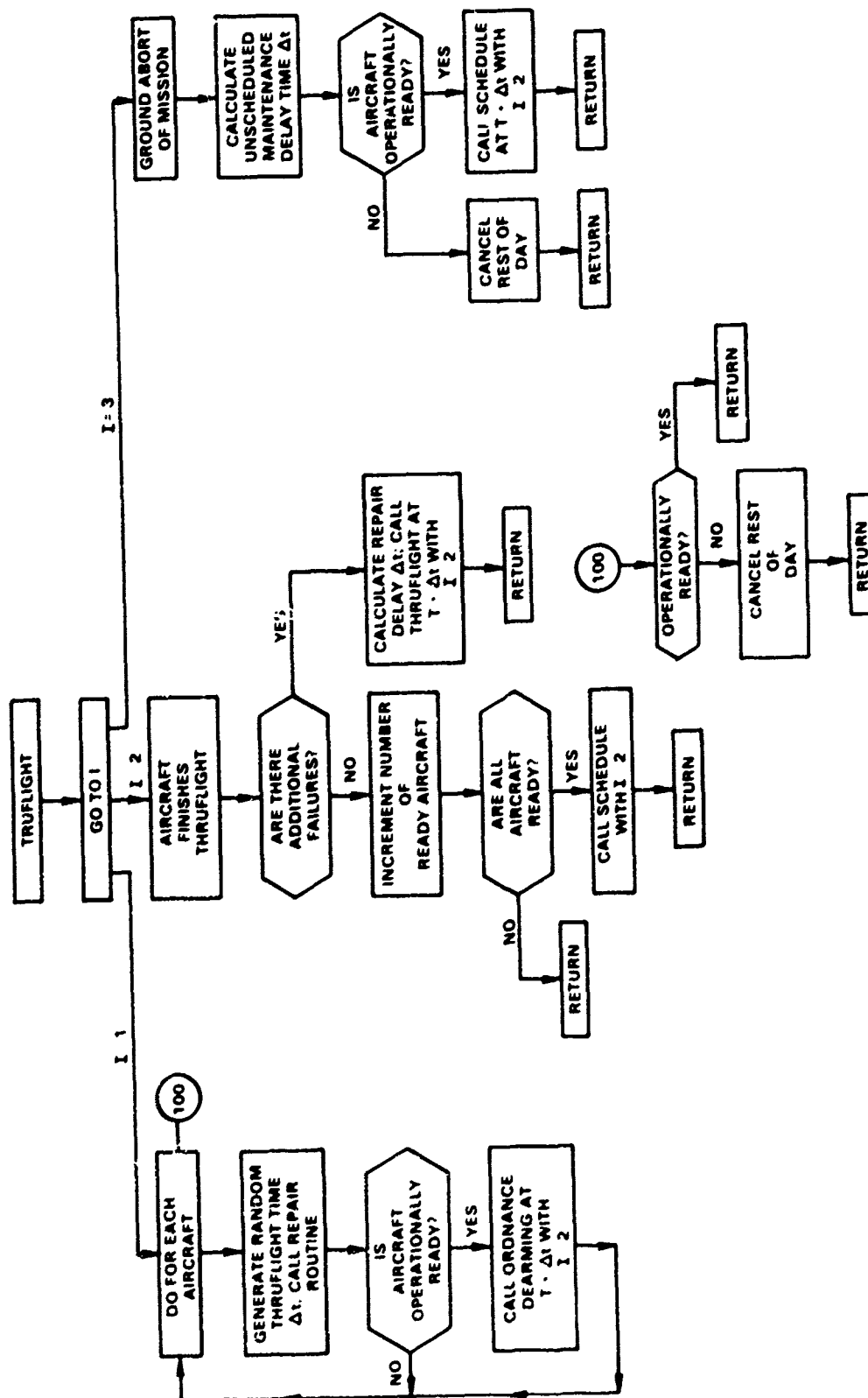


FIGURE 6. THRUFLIGHT SUBFUNCTION(1.2)

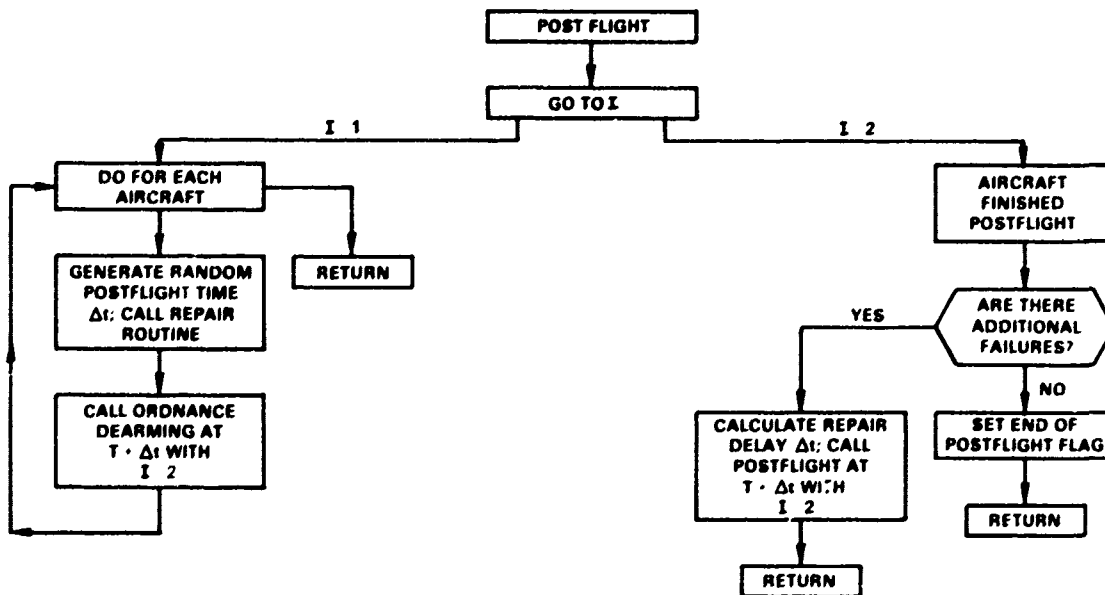


FIGURE 7. POSTFLIGHT SUBFUNCTION(1.3)

The input items for each of the subfunctions are: the number of weapons carried; the mean and standard deviation of the loading plus arming time per weapon; and the mean and standard deviation of the unloading plus dearming time per weapon.

The total time required to load or unload the ordnance is computed from the input statistics defining a normal time distribution and the total number of weapons which must be either loaded or unloaded. There are no nominal calculations, aircraft aborts, or mission aborts associated with this function.

In the Monte Carlo Routine (MCPN02), each of the available subfunctions is called to determine the total loading or de-arming time for each aircraft. Control passes to fuel loading after de-arming. After loading, control returns to preflight or thruflight as appropriate.

Figure 8 shows the logic flow for each of the subfunction routines, General Purpose Munitions (MSB021) and Rockets (MSB022).

Fuel

This function provides a means of managing the aircraft fuel requirements. Three subfunctions are available for fuel loading, monitoring c. fuel used, and air-refueling. There are no direct nominal calculations

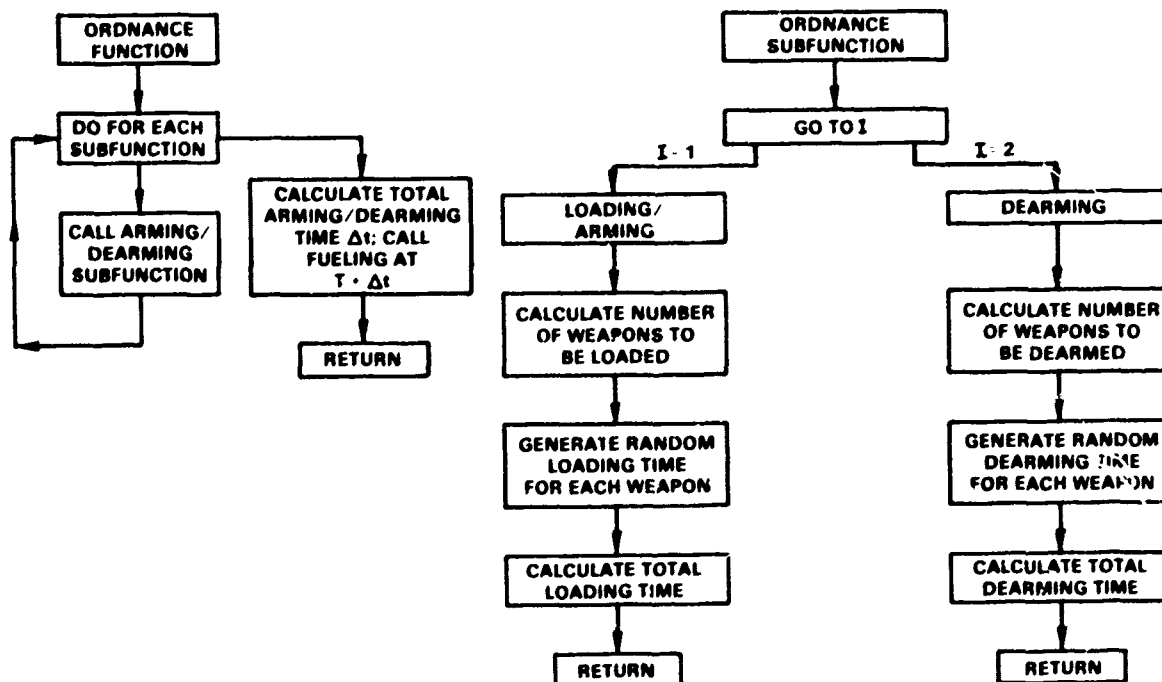


FIGURE 8. ORDNANCE FUNCTION/SUBFUNCTIONS(2.X)

for this function, however, the fuel flow rate during flight is one of the aircraft states provided by the aircraft flight simulation.

An aircraft abort occurs if fuel monitoring or refueling states are unavailable. A mission abort occurs if no modes are available for air-refueling.

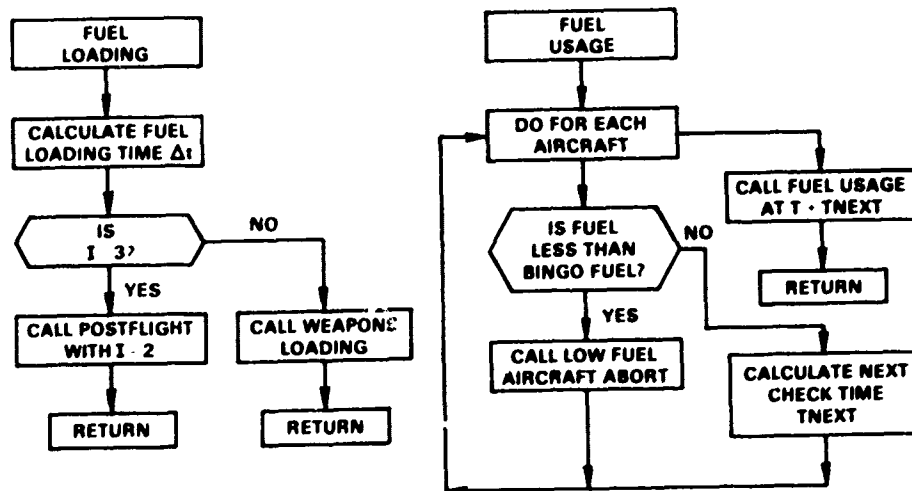
The Monte Carlo routine (MCFN03) transfers control to the appropriate subfunction.

Fuel Loading

Figure 9a shows the loading routine (MSB031). When fuel loading is completed control passes to thru-flight or postflight at appropriate.

Fuel Usage

Figure 9b shows the logic flow for this routine (MSB032). This subfunction aborts an aircraft if the remaining fuel is less than



a. Fuel Loading Subfunction
(3.1)

b. Fuel Usage Subfunction
(3.2)

FIGURE 9. FUEL SUBFUNCTIONS

that required to complete the flight plus the required reserve. The subfunction is called periodically (when it is on) based on the flow rate and fuel status.

Air Refueling

Figure 10 shows the control logic for this subfunction (MSB033). Refueling occurs when the subfunction is turned on. The time of hookup is determined from a uniform probability distribution specified on input by the minimum and maximum hookup time. Several aircraft can be refueled simultaneously, the exact number being specified as input. The time required to refuel is calculated as a function of the amount of fuel to be called and the refueling rate, which is also specified as input.

Flight

This function provides a means of specifying the equipment requirements for various portions of the mission. Five subfunctions—Launch, Aircraft Abort, Mission Abort, Aircraft Loss and Landing, are available. Nominal calculations required by Flight are performed by the aircraft flight simulations. Abort logic is given under each subfunction.

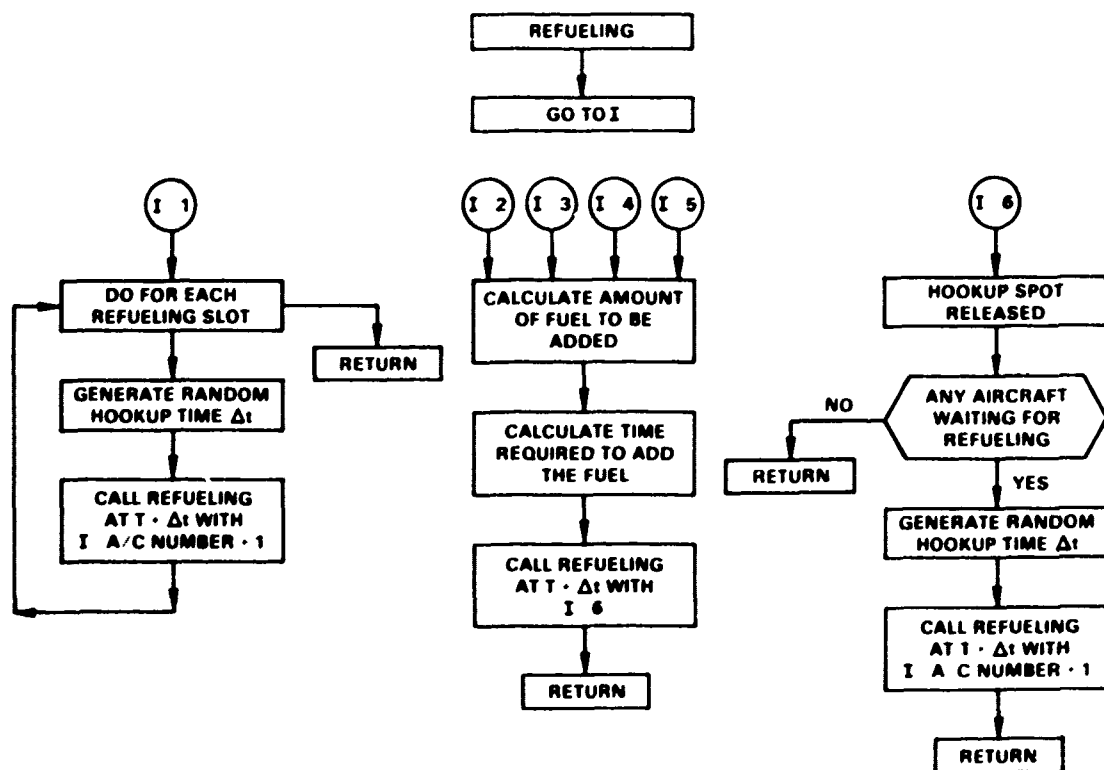


FIGURE 10. REFUELING SUBFUNCTION(3.3)

The Monte Carlo Routine MCFN04 transfers control to one of the subfunctions.

Launch

Figure 11a shows the control logic for this routine (MSB041). A random sortie launch time is drawn from a log-normal distribution defined by the input data. This time represents the interval between engine start and take-off. At take-off subfunctions 2-4 are turned on, and launch is turned off. The launch subfunction uses only the time data given with the first mode.

A ground abort of the mission occurs if either an aircraft has no available equipment state, or no mode requirement is satisfied.

Aircraft Abort

There are no program calculations associated with this routine. The aircraft equipment states associated with this subfunction allow determination of an aircraft abort. In addition, the mode requirements define conditions for which the abort of one aircraft would cause the abort of a second aircraft. For this subfunction, each aircraft must satisfy one of the OR conditions of the mode specification. As an example, consider the following mode definition for a flight of four aircraft:

$$A1 \cdot B1 + C1 \cdot D1$$

If aircraft A aborts, any other subfunction would assume that C1·D1 is satisfactory. For this particular subfunction, since A is unavailable, A1·B1 is not satisfied and aircraft B does not appear in another OR condition. Therefore, aircraft B aborts the sortie also. This provides the user the ability to define conditions for which the abort of one aircraft will cause the abort of another aircraft.

Mission Abort

The mode/state requirements of this subfunction are used to define when a sortie must be aborted. If no mode is available, the mission is aborted.

Aircraft Loss

This subfunction is used to define the set of equipment required to keep an aircraft airborne. If no aircraft equipment state is available, the aircraft is lost.

Landing

Figure 11b shows the program control for this routine (MSB045). Control transfers to the schedule routine upon landing. If no landing equipment state is available, the aircraft is counted as lost.

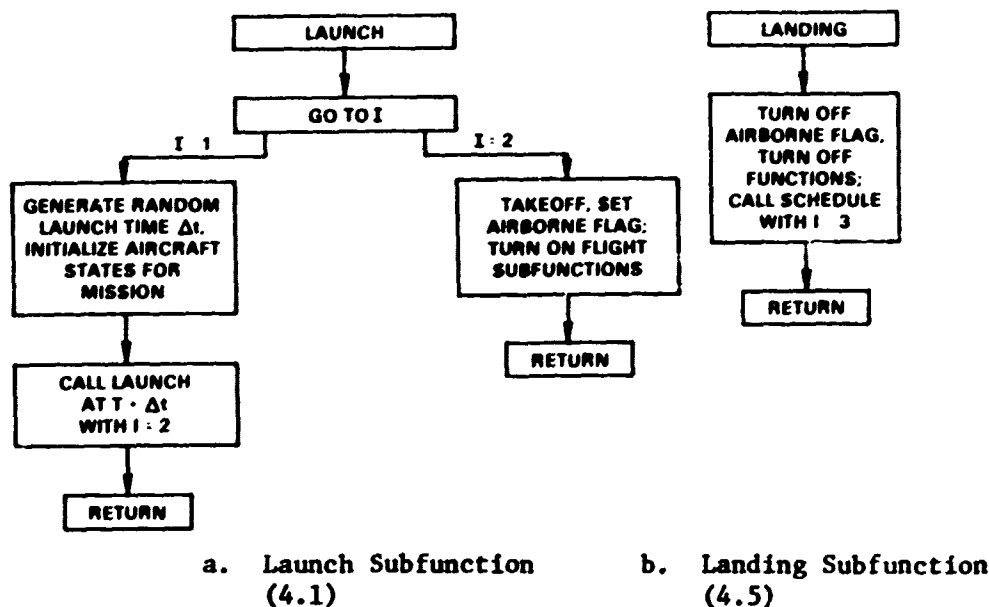


FIGURE 11. FLIGHT SUBFUNCTIONS

Mission

This function provides a means of specifying the operations schedule and the cost of various portions of the mission. There are no nominal calculations, aircraft aborts, or mission aborts associated with this function.

The Monte Carlo routine MCFN05 transfers control to the subfunction routines.

Schedule

Figure 12 shows the logic flow for the schedule routine (MSB051). The schedule subfunction is the overall mission scheduler for the nominal portion of the simulation. The schedule, utilizing the input data, manages the starting times for the individual sorties and the individual days. All maintenance actions and all flights are controlled by this subfunction. If a delay occurs in the ground maintenance functions, the scheduler may cancel a sortie if the input maximum delay time is exceeded.

This subfunction is called initially to begin the simulation, at the end of thruflight and preflight maintenance, and at the end of each sortie.

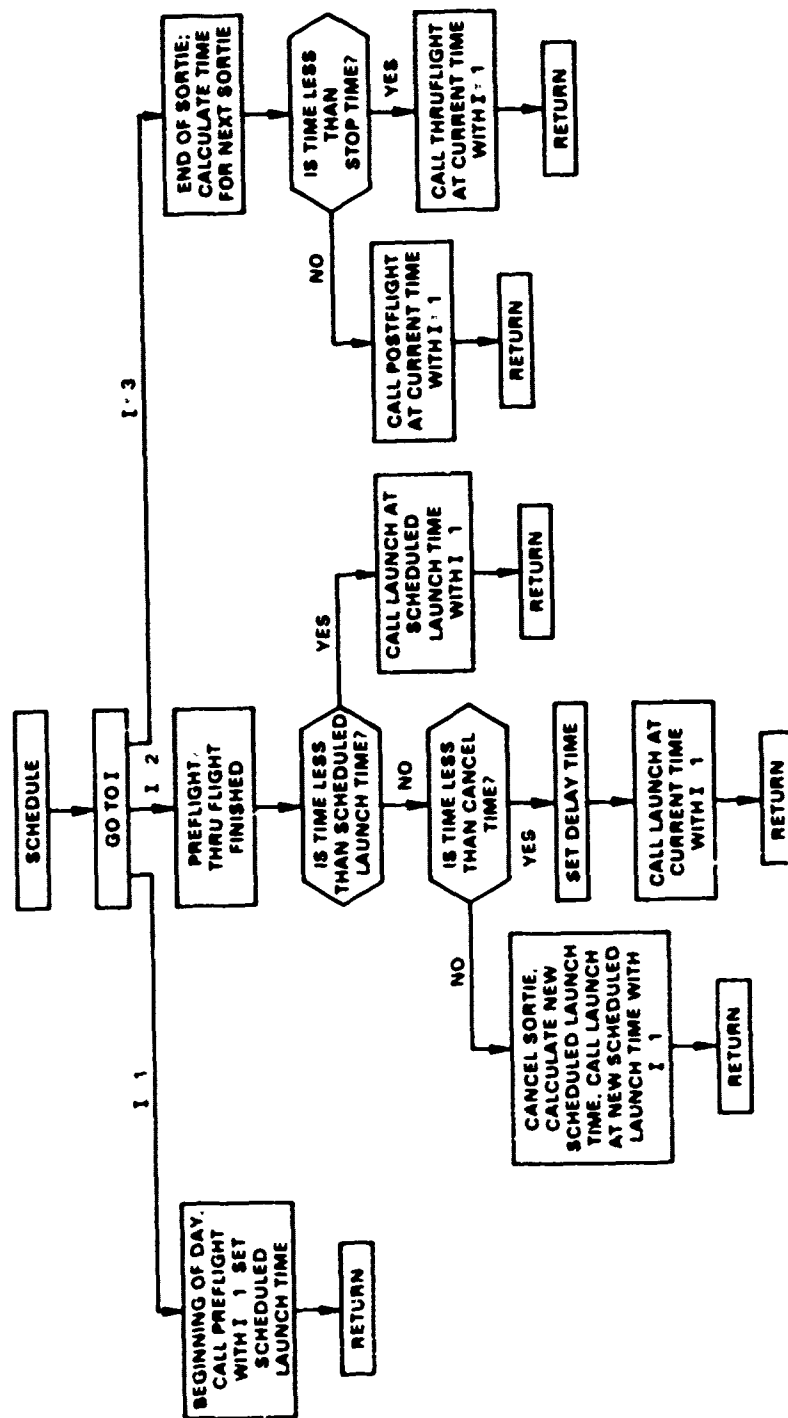


FIGURE 12. SCHEDULE SUBFUNCTION(S.1)

Cost Accumulation

The cost accumulation subfunction (MSB052) is called after each simulation period to assess the cost of that Monte Carlo trial. The input data gives costs at the squadron level, so that the costs accumulated must be the fractional part associated with the number of aircraft simulated. The costs currently accumulated are:

- (1) Fuel
- (2) Ordnance
- (3) Maintenance
- (4) Replacement
- (5) Flight (summed on sorties and flight hours)
- (6) Flight Crew
- (7) Munitions Crew
- (8) Command Staff
- (9) Miscellaneous Personnel
- (10) Amortization

Formation

The purpose of this function is to specify the position of flight members relative to the lead aircraft. The user specifies the distance right, behind and above the leader for up to three supporting elements. The data for this subfunction is used during the nominal evaluations to determine the position state vector of each aircraft.

Navigation

The navigation function includes two subfunctions - radio aided navigation and self-contained navigation. These two subfunctions provide the capability of computing and considering navigation errors. Two types of navigation errors are considered - a fixed position navigation error and a per unit time navigation error. The navigation error model is defined by:

$$X(t_2) = a X(t_1) + b X_N \quad (16)$$

where

$X(t_2)$ = current navigation error

$X(t_1)$ = error at previous time t ,

X_N = zero mean, normal random deviate with unit variance

The constants a and b are calculated such that

$$E[X(t_2)^2] = \sigma^2 \quad (17)$$

and

$$E[X(t_1)X(t_2)] = \rho\sigma^2 \quad (18)$$

where

$E[\cdot]$ = expected value function

σ = one sigma navigation error

ρ = correlation coefficient

An exponential time correlation is assumed for the navigation errors, thus

$$\rho = \exp[-(t_2 - t_1)/\tau] \quad (19)$$

where

τ = correlation time constant

Therefore, the constants a and b are given by:

$$a = \rho \quad (20)$$

$$b = [1 - \rho^2]^{1/2} \quad (21)$$

There are no nominal calculations or aircraft aborts associated with navigation. A mission abort occurs if the self-contained navigation subfunction fails. If the radio aided navigation fails, a switch to self-contained navigation is attempted. If the switch is successful, the mission is continued; otherwise, a mission abort occurs.

The Monte Carlo routine MCFN07 transfers control to the appropriate subfunction.

Radio Aided Navigation

Figure 13 shows the program control for this routine (MSB071). The general form of the navigation error is:

$$\sigma = \sigma_0 + \sigma_1 t \quad (22)$$

For this subfunction, σ_0 is input by the user and σ_1 is set to zero.

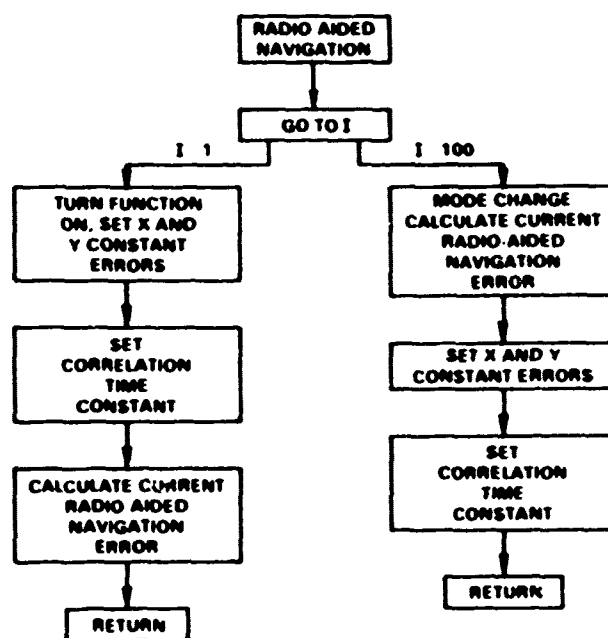


FIGURE 13. RADIO-AIDED NAVIGATION SUBFUNCTION(7.1)

Self-Contained Navigation

Figure 14 shows the logic flow for this routine (MSB072). For this subfunction, σ_0 is set to zero and σ_1 is input by the user.

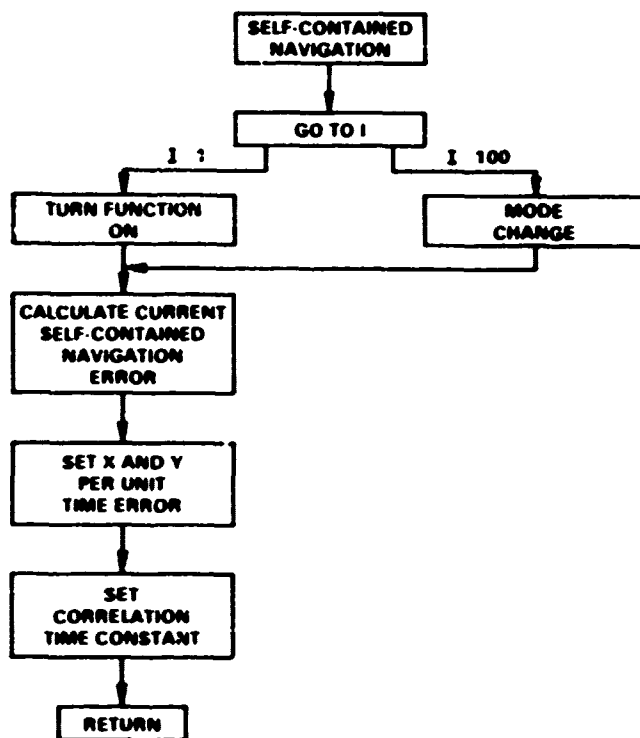


FIGURE 14. SELF-CONTAINED NAVIGATION SUBFUNCTION(7.2)

Navigation Update

The navigation update function includes three subfunctions - automatic update, radar update, and visual update. The subfunctions allow the user to specify up to three different types of update.

The navigation update subfunctions calculate the sensor field of view and determine if the checkpoint is within the sensor field of view and if the checkpoint has been detected. Once the checkpoint has been detected, the accuracy of the navigation update is computed. The navigation update model is defined as follows:

Calculate the ground width of the sensor field of view:

$$W = \frac{H \tan\left(\frac{\theta_h}{2}\right)}{\sin(\delta)} \quad (23)$$

where

W = one-half of the ground width of sensor field of view

H = Aircraft altitude

θ_h = Total horizontal angular field of view

δ = Depression angle to the center of the field of view

The cross track navigation error is computed as

$$X_m = \frac{V_y X_n - V_x Y_n}{\sqrt{V_x^2 + V_y^2}} \quad (24)$$

where

X_m = Cross track navigation error

V_x = X component of velocity

V_y = Y component of velocity

X_n = X navigation error

Y_n = Y navigation error

The checkpoint one sigma variation is

$$C_O = CEP/1.17741 \quad (25)$$

where

C_O = Checkpoint one sigma variation

CEP = Circular error probable location of checkpoint

The checkpoint is within the sensor field of view if

$$|X_m - C_O R_n| \leq W \quad (26)$$

where

X_m = Cross track navigation error

C_O = checkpoint one sigma variation

R_n = Normal random variate with mean 0 and unit variance

There are no nominal calculations, aircraft aborts, or mission aborts associated with this function. The Monte Carlo routine MCFN08 transfers control to the appropriate subfunction.

Figure 15 shows the logic flow for each of the update subfunctions - Automatic (MSB081), Radar (MSB082), and Visual (MSB083).

Communications

Two subfunctions are provided - interflight and external communications to assess the reliability of the communications equipment. Loss of all aircraft equipment states for interflight communications causes an aircraft abort. Loss of all modes for either subfunction causes a mission abort.

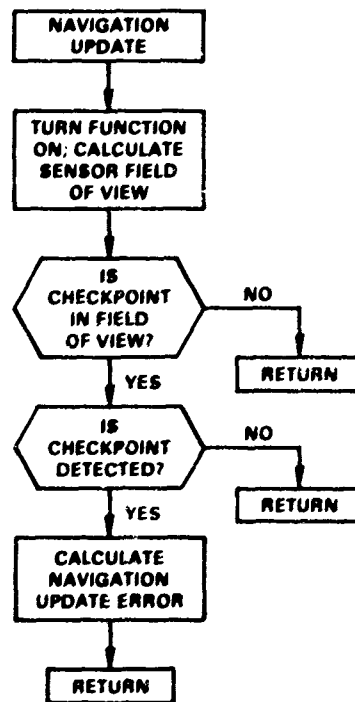


FIGURE 15. NAVIGATION UPDATE SUBFUNCTION(8.X)

Survivability

The survivability subfunctions have two primary purposes. The first is to generate a random time of hit for each aircraft. It is assumed that the probability of hit is a linear sum of a uniform and an exponential distribution. A call to the survivability subfunction is placed in the event table at the resulting time.

The second purpose of the survivability subfunctions is to process the aircraft hits as they occur. When the simulation reaches the time of hit, the survivability subfunction is called to assess the damage.

The input data items to these subfunctions are the constant probability of hit, the per unit time probability of hit, and the probability of aircraft kill.

When a hit is being processed, a uniform random number representing the probability of aircraft kill is generated. This number is compared to the input probability of kill to determine if the aircraft has been lost. A lost aircraft is removed from the mission, and a check is made to determine if the mission must be aborted.

When examining an aircraft which has only been damaged, the vulnerability associated with each hardware item is checked to determine if the item has failed because of the hit. The failure of a hardware item requires that the subfunction modes be checked to determine if mode regression is possible.

There are no nominal calculations or aircraft aborts associated with this function. It is assumed that the loss of critical ECM equipment could make the aircraft too vulnerable to enemy fire, hence loss of all modes for a subfunction causes a mission abort. To negate this option, the user only needs to specify one extra "trap" mode with no equipment requirements.

The Monte Carlo Routine MCFN80 transfers control to the appropriate subfunction.

Figure 16 shows the control logic for any of the five subfunctions (MSB101-MSB105). The five subfunctions are provided so that the user may have direct control over when each is used. For example, a particular mission profile may progress through defensive zones with different probabilities of survival. The user can key the use of each subfunction (with different data) to waypoints defining the flight profile. This switching cannot occur with the mode structure since equipment failures, not geographical location, causes a regression to an alternate mode.

Target Acquisition

Two subfunctions are provided for target acquisition - display and visual. Significant calculations are required for both subfunctions for the nominal and Monte Carlo evaluations. The nominal routine (FUN11) transfers control to the appropriate nominal subfunction.

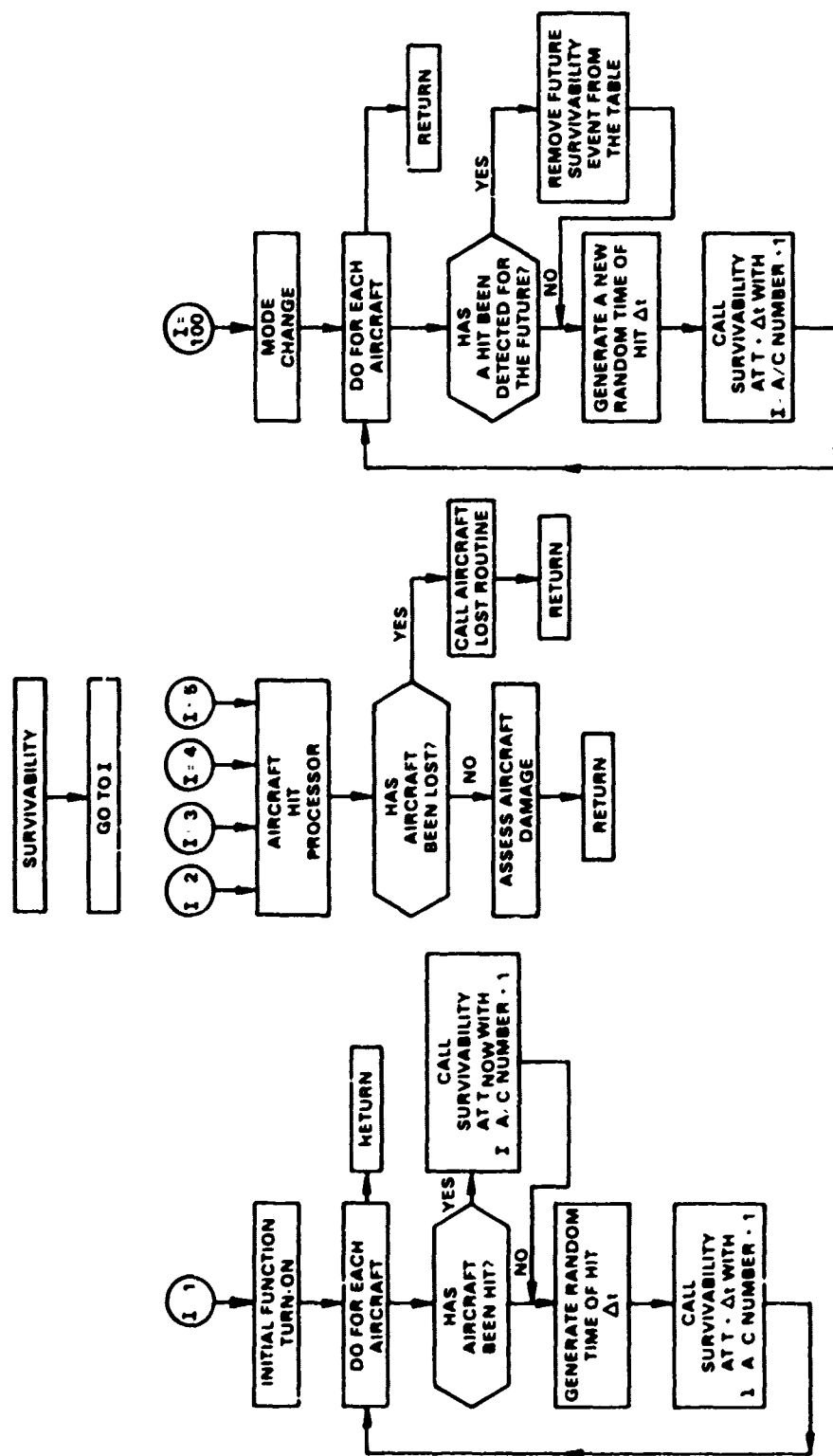


FIGURE 16. SURVIVABILITY SUBFUNCTION(10.X)

Nominal Computations

The display and visual routines (SUB111 and SUB112) for the nominal evaluation determine the ground area searched. The coordinates of the field-of-view (FOV) are calculated and stored for each mode.

Figure 17 shows the geometry of the angles defining the FOV. Each mode of the acquisition subfunction provides data for the angles;

\emptyset = depression to center of FOV

ψ = side angle to center of FOV

θ_v = vertical height of FOV

θ_h = horizontal width of FOV

To determine the location of point 1 shown in Figure 17, consider a coordinate frame rotated from the aircraft reference by the angles \emptyset and $\emptyset - \theta_v$. This defines a reference frame whose X axis is the intersection of the vertical plane through the FOV and the plane defining the top of the FOV. The transformation describing this rotation is:

$$B_{AS} = \begin{bmatrix} \cos\alpha \cos\psi & -\sin\psi & -\sin\alpha \cos\psi \\ \cos\alpha \sin\psi & \cos\psi & -\sin\alpha \sin\psi \\ \sin\alpha & 0 & \cos\alpha \end{bmatrix} \quad (27)$$

where

B_{AS} = sensor to aircraft transformation

$$\alpha = \emptyset - \frac{\theta_v}{2}$$

The vector to point 1 in this sensor frame is

$$[X] = L \begin{bmatrix} \cos \beta \\ -\sin \beta \\ 0 \end{bmatrix} \quad (28)$$

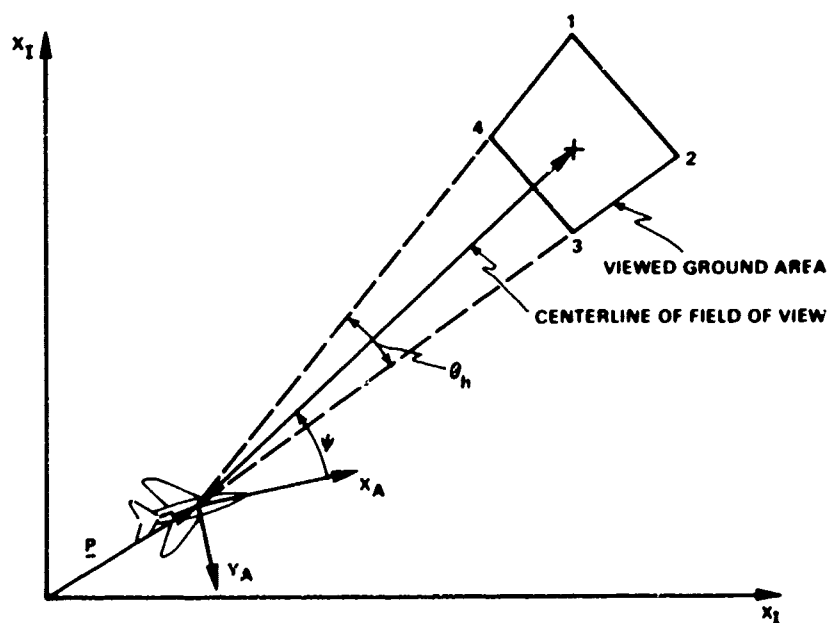
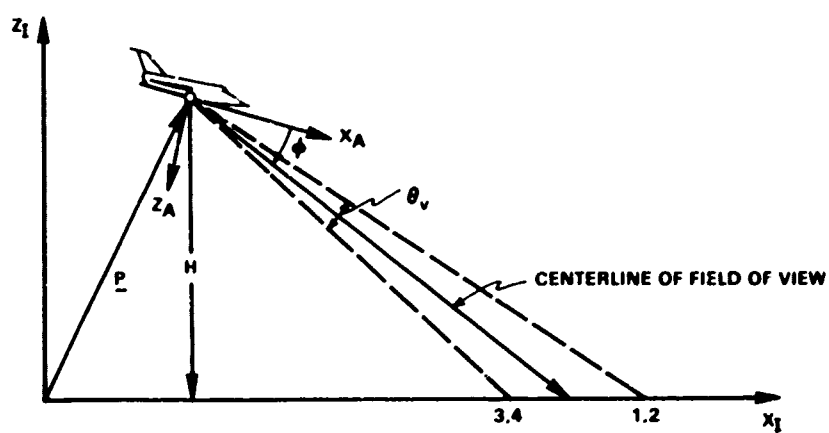


FIGURE 17. FIELD OF VIEW GEOMETRY

where

L = length of X

$\beta = \theta_h/2$

The vector X in inertial co-ordinates is

$$[X] = L B_{IA} B_{AS} \begin{bmatrix} \cos \beta \\ -\sin \beta \\ 0 \end{bmatrix} + [P] \quad (29)$$

where

$[P]$ = aircraft position vector

B_{IA} = aircraft to inertial transformation.

The transformation matrix B_{IA} and P are provided as part of the aircraft state vector from the flight simulation. To determine L note that the Z component of $[X]$ must be $-H$. Since B_{IA} , B_{AS} , and B are known, let

$$[Y] = B_{IA} B_{AS} \begin{bmatrix} \cos \beta \\ -\sin \beta \\ 0 \end{bmatrix} \quad (30)$$

$$= \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} \quad (31)$$

Since

$$[X] = L [Y] \quad (32)$$

and

$$x_3 = -H \quad (33)$$

then

$$L = -H/y_3 \quad (34)$$

Knowing L the X, Y ground co-ordinates of point 1 are found from equation (29). Each of the four points are found using the following angles:

$$1 - \alpha = -\theta - \frac{\theta_v}{2}, \quad \beta = \theta_h/2 \quad (35)$$

$$2 - \alpha = \theta - \frac{\theta_v}{2}, \quad \beta = \theta_h/2 \quad (36)$$

$$3 - \alpha = \theta + \frac{\theta_v}{2}, \quad \beta = \theta_h/2 \quad (37)$$

$$4 - \alpha = \theta + \frac{\theta_v}{2}, \quad \beta = -\theta_h/2 \quad (38)$$

The co-ordinates of the four points defining the ground area are calculated at the beginning and end of each straight segment of flight during the time the subfunction is turned on.

The Monte Carlo routine (MCFN11) transfers control to the appropriate subfunction and suspends additional target acquisitions during attack passes.

Monte Carlo Computations

Figure 18 shows the control logic for the display (MSB111) and visual (MSB112) subfunctions. During the Monte Carlo simulation the points defining the FOV for the current mode are used to determine if any target falls within the field of view. Figure 19 shows the total ground area covered for a typical search segment. To determine if a target falls within the FOV each of the four quadrilaterals defined by the points

$$A. (1-1'-2'-2) \quad (39)$$

$$B. (2-2'-3'-3) \quad (40)$$

$$C. (3-3'-4'-4) \quad (41)$$

$$D. (4-4'-1'-1) \quad (42)$$

is checked to see if the target location (X_t, Y_t) is an interior point. To determine if (X_t, Y_t) is an interior point to A , let $[Y_i]$ be the vector describing each side of quadrilateral:

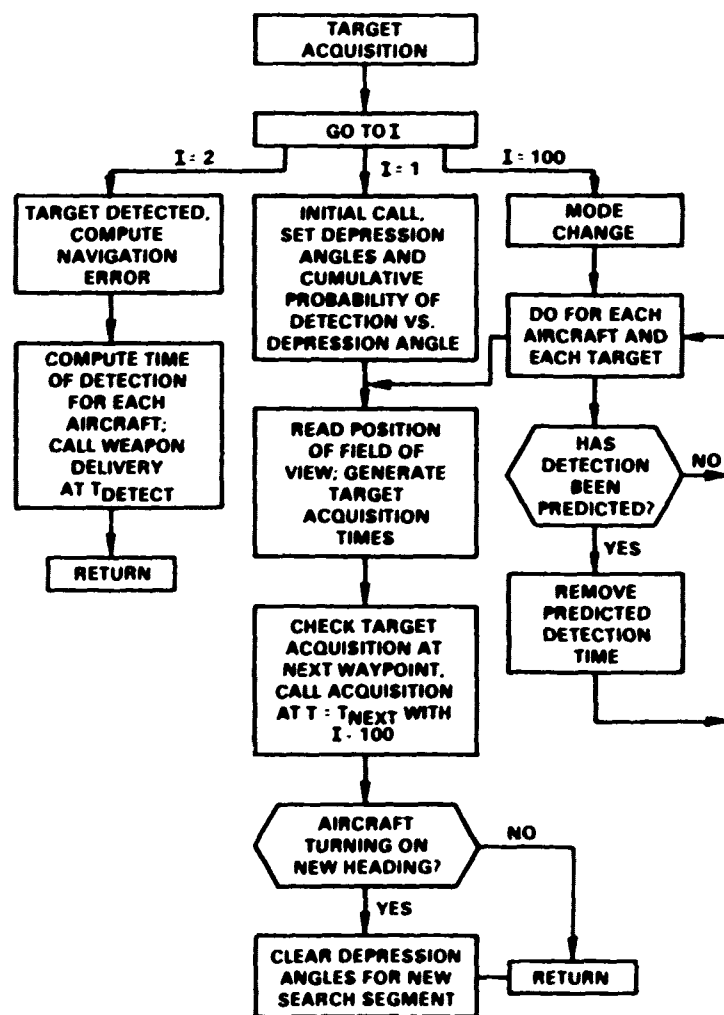


FIGURE 18. TARGET ACQUISITION SUBFUNCTION(11.X)

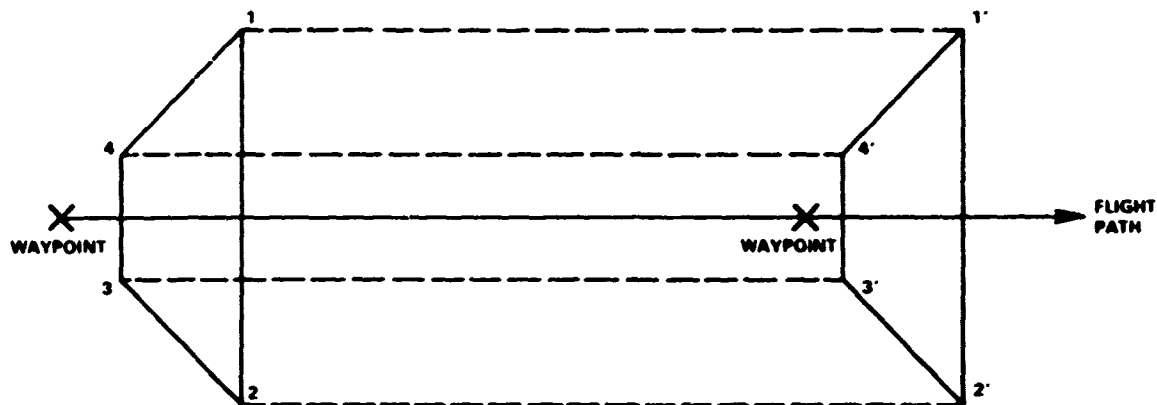


FIGURE 19. FIELD OF VIEW DURING SEARCH

$$[Y_1] = [X_1] - [X_1'] \quad (43)$$

$$[Y_2] = [X_1'] - [X_2'] \quad (44)$$

$$[Y_3] = [Y_2'] - [X_2] \quad (45)$$

$$[Y_3] = [X_2] - [X_1] \quad (46)$$

Choose vectors normal to the sides so that

$$[Z_i] = \begin{bmatrix} y_2 \\ -y_1 \end{bmatrix}_i \quad (47)$$

Let $[P_i]$ be any point on $[Y_i]$, then the sign of the vector product

$$([X_t] - [P_i]) \cdot [Z_i] \quad (48)$$

assigns $[X_t]$ to the right or left of $[Y_i]$. The point $[X_t]$ is interior to A only if the dot products for $i = 1, 4$ all have the same sign. Figure 20 describes the situation for both an interior and an exterior point.

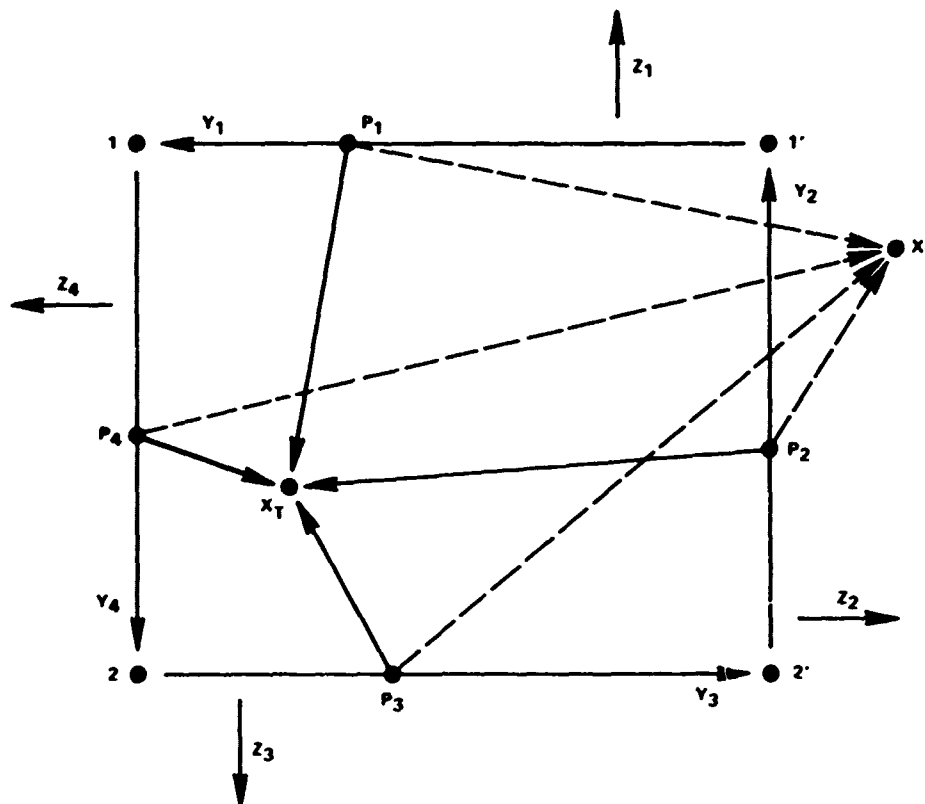


FIGURE 20. INTERIOR/EXTERIOR VECTOR RELATIONSHIPS

When the target falls within the FOV, a random depression angle is obtained from the user table of detection probability versus depression angle. Based upon the aircraft flight profile, the time when that depression angle occurs is calculated and a target detection event is created at that time. If the next waypoint is reached prior to detection, the predicted detection is cancelled and another check for detection is made based on the FOV for the new flight segment.

All targets specified by the user are checked for detection during each search segment, with attack passes occurring based on the sequence of detection. Thus, for relatively close targets, the order of attack can be different than the order of target locations. After an attack against one target, the acquisition process is resumed for the remaining targets. This feature allows a user to simulate a target of opportunity type mission.

Abort Logic

There are no aircraft aborts due to loss of acquisition equipment items. A mission abort occurs only if all possible modes of both subfunctions have failed.

Weapon Delivery

Two weapon delivery subfunctions are available, manual and automatic. A significant feature of the updated weapon delivery function is that ordnance and target types are keyed to the delivery modes. This gives the user the flexibility of considering various ordnance mixes for a multiple target sortie.

Nominal Routine

The nominal weapon delivery function (FUN12) searches through the modes specified by the user to organize individual mode chains for each target. This is done for the sake of computer execution efficiency so that only the modes associated with a given target need be searched during the Monte Carlo simulation.

Monte Carlo Routine

Figure 21 shows the control logic for the weapon delivery function (MCFN12). This function is activated by the target acquisition function at the time of target detection. Since the improved acquisition function provides the target range at detection, each of the weapon subfunctions are called to determine which delivery modes can be used based upon weapon fall ranges and rollin times. Depending upon the number of aircraft available, either a direct attack mode or a go-around mode will be selected. For subsequent attack passes, the range constraint is not considered.

A unique feature of the weapon delivery function is that a subfunction/mode status is maintained for each aircraft. Thus, it is possible for one aircraft to use the automatic release subfunction and another aircraft to use another mode or the manual subfunction.

Unguided Weapon Delivery Subfunctions

Figure 22 shows the control logic for the weapon delivery subfunctions, manual (MSB121) and automatic (MSB122). Entries with I=3 cause the direct attack and go-around modes to be selected. The function routine determines the actual mode to be used.

Mode changes due to equipment failure have no immediate impact if weapon delivery has not been activated. When a weapon delivery run is committed and a mode regression occurs, only a mode with a release range matching the committed range will be used. Otherwise, the aircraft with the failure cannot attack on that pass.

Abort Logic

An individual aircraft does not abort if no equipment states remain. If that aircraft was initially in the automatic subfunction, the manual subfunction will be used if possible. If none of the aircraft can perform the weapon delivery function, the mission is aborted.

Target

The target function manages the number of attack passes and target location uncertainty for up to five targets (subfunctions 13.1 - 13.5). Figure 23 describes the logic flow for this routine (MCFN13). Note that there are two levels of target destruction accumulated. These are based on primary and secondary kill radii.

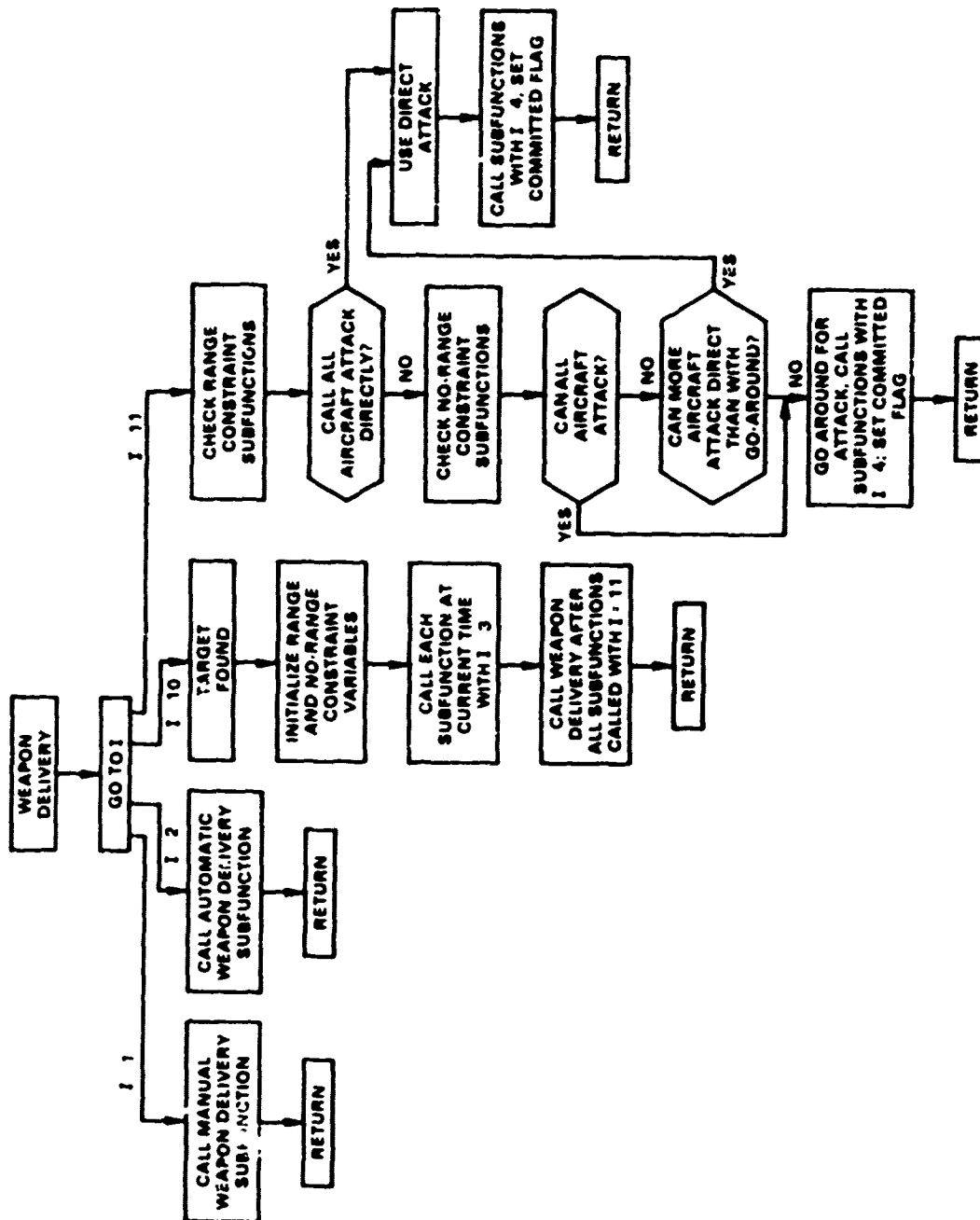


FIGURE 21. WEAPON DELIVERY FUNCTION(12.0)

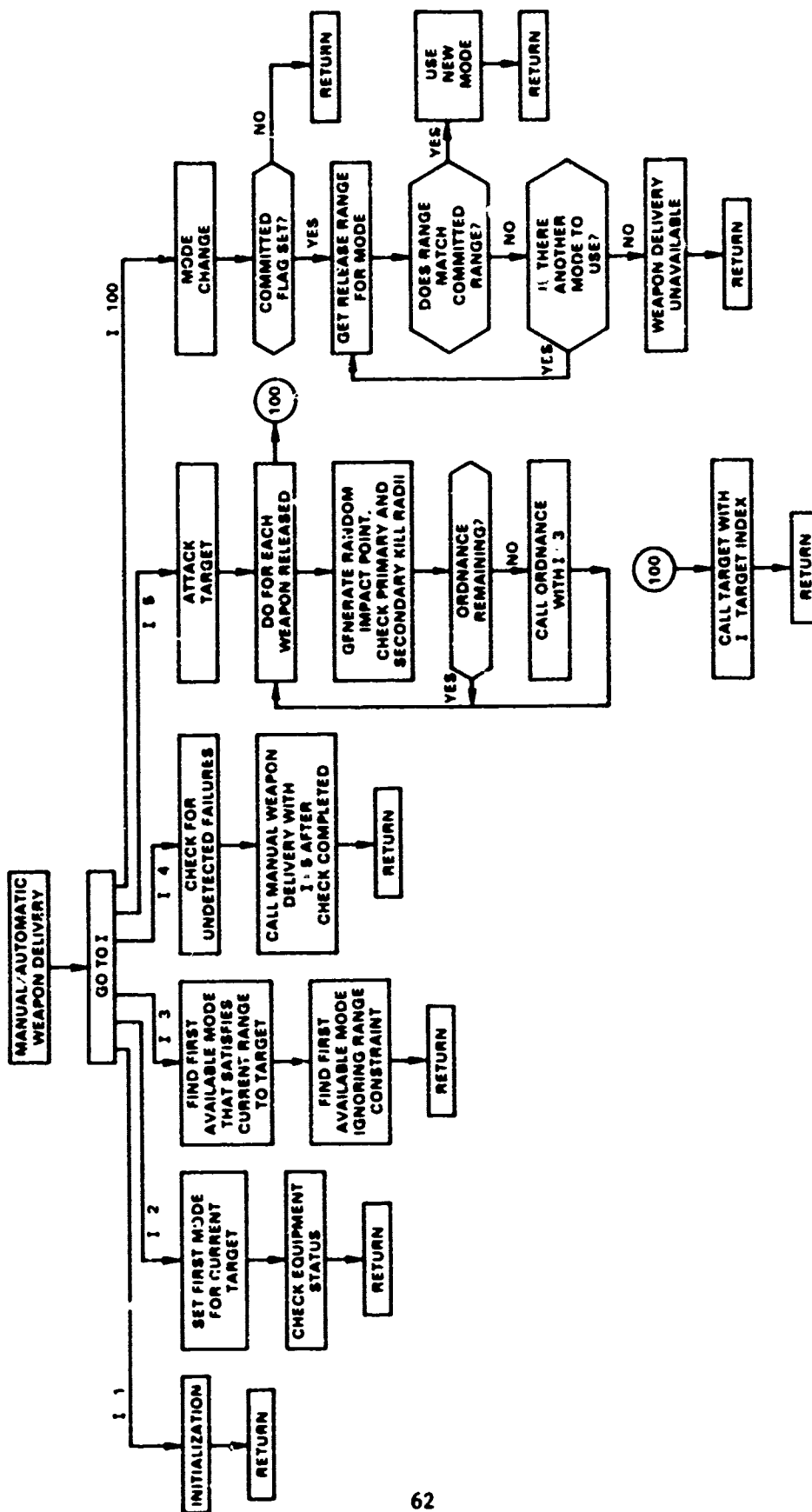


FIGURE 22. MANUAL/AUTOMATIC UNGUIDED WEAPON DELIVERY SUBFUNCTION(12.1/12.2)

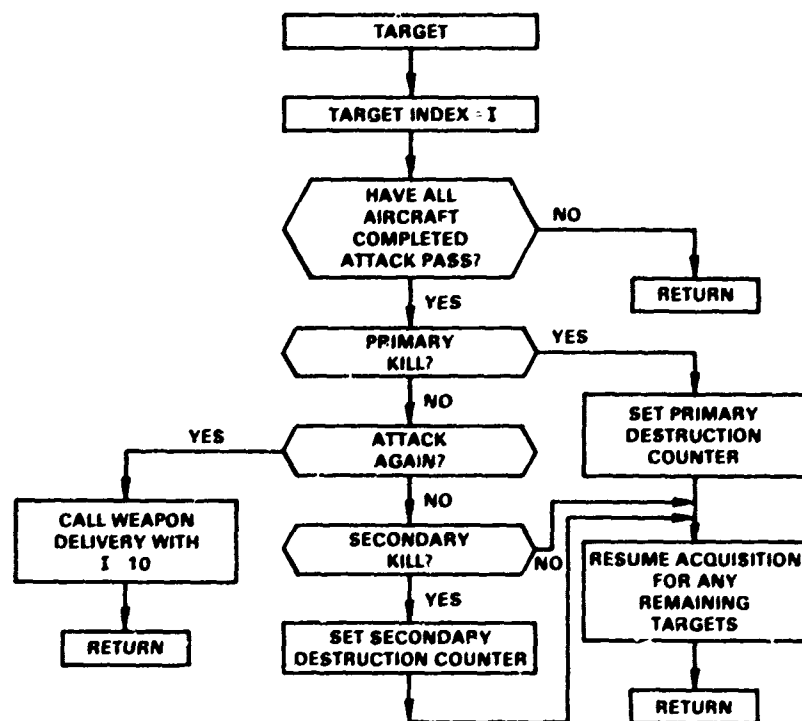


FIGURE 23. TARGET FUNCTION(13.0)

There are no nominal calculations, aircraft aborts, or mission aborts associated with this function.

V. INTERACTIVE GRAPHICS PROCESSOR

General Description

The AEP program is incorporated in an interactive graphics processor. The main objectives in providing an interactive capability are to:

- Provide the user with an easier means of communicating with the computer
- Help verify that inputs are free of the common card punching or typing mistakes
- Provide a data bank for storing and retrieving input data
- Provide sufficient instructions within the interactive software to avoid the need for consulting computer program manuals
- Provide graphical representation of input data and program results.

Figure 24 shows a diagram of the interactive implementation. The dashed line encloses a batch program represented by a set of code and an input deck.

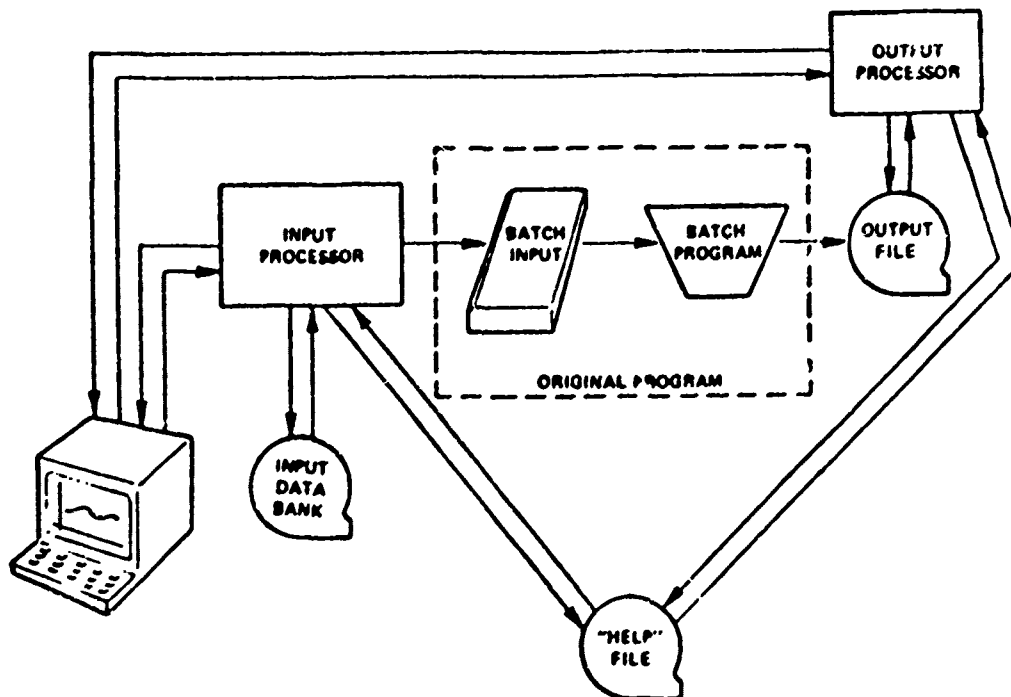


FIGURE 24. APPLICATION OF INTERACTIVE GRAPHICS TO EXISTING BATCH PROGRAMS

The AEP is a batch program, even though it is automatically executed from a remote interactive terminal. The input and output processors are used to communicate with the user for problem set-up and review of the the output. New data is stored in convenient subsets for later use. A very important "Help" file and on-line user's manual are available to aid the user in communicating with the processor and associated programs.

Figure 25 shows a sample operation of the interactive processor. A double dash appears whenever a user input is requested. These have been numbered to facilitate the following explanation of the inputs and responses:

- (1) Several users can simultaneously operate the program with their own data file. Thus, an ID code is required to determine which data file to attach.
- (2) An AEP command has been requested. A question mark(?) can be entered at any time for explanation of available options.
- (3) After giving a response, the processor again requests an AEP command. Any of the available commands can be entered followed by a question mark for a further explanation of that command and a data entry format (if applicable).
- (4) The user entered a command to enter the Flight Profile portion of the processor.
- (5) Previously created Flight Profiles are stored in the data file along with an alphanumeric description entered at the time they were stored.
- (6) After selecting a previously stored profile, the processor requests a FP Command. The available commands are not the same as the AEP Commands.
- (7) When a command requires a particular format for entry, each entry is defined and an example is given.
- (8) A command to list the waypoints of the Flight Profile was entered.

```

ENTER USER ID
(1)  -- DEMO
AEP COMMAND
(2)  -- ?
EXECUTIVE (AEP) COMMANDS
EQUIP   FUR   WD   WDDECK   WDOUT   FP
MARSAM  AEPDECK  AEPDUT  NEWS  QUIT
AEP COMMAND
(3)  -- FP?
FLIGHT PROFILE GENERATION
AEP COMMAND
(4)  -- FP
ENTER PROFILE ID
(5)  -- ?
ENTER NUMBER ID OF STORED PROFILE, ENTER 0 TO CREATE NEW PROFILE
ENTER SHOW FOR LIST OF STORED PROFILES
ENTER PROFILE ID
-- SHOW
1  NRL DEMO PROFILE
ENTER PROFILE ID
-- 1
FP COMMAND
(6)  -- ?
FLIGHT PROFILE (FP) COMMANDS
ENTER VALID COMMAND WITH REQUIRED PARAMETER LIST
I D C T LIST FLY PLAN ALT VEL SAVE QUIT
FP COMMAND
(7)  -- I?
INSERT NEW WAYPOINT AS FOLLOWS I,ID,X,Y,H,V,ON,OFF
ID=POINT AFTER WHICH DATA IS TO BE INSERTED
X,Y=COORDINATES(NM), H=ALTITUDE(FT), V=SPEED(KTS),
ON=FUNCTIONS TURNED ON, OFF=FUNCTIONS TURNED OFF.
FIVE ON/OFF NUMBERS MAY BE ENTERED PER WAYPOINT.
THE 14 INPUT PARAMETERS X THRU OFF(5) MAY BE ENTERED WITHOUT
THE LETTER CODE. IF PARAMETERS ARE SKIPPED THE LETTER CODE
MUST BE USED. ZERO VALUES ARE ASSUMED IF NOT INPUT.
EX - I,4,100.,10.,V=250. SETS X=100.,Y=10.,SPEED=250. AFTER POINT 4
FP COMMAND
-- LIST?
DISPLAY LIST OF CURRENT VALUES. POINTS ARE RESEQUENCED TO REFLECT
PREVIOUS COMMANDS
FP COMMAND
(9)  -- LIST

```

FIGURE 25. SAMPLE OPERATION OF THE INTERACTIVE PROCESSOR

ID	X	Y	H	V	ON	OFF
1	0.00	0.00	0.	250.	302 702 902 1001	
2	10.00	0.00	10000.	350.		
3	20.00	0.00	20000.	400.		
4	100.00	0.00	20000.	400.		
5	110.00	10.00	500.	450.	1002	10
6	150.00	50.00	500.	450.	1003	10 9
7	170.00	70.00	500.	450.		
8	170.20	70.20	2000.	450.	1101	
9	172.00	72.00	2000.	450.	1004	10
10	176.00	76.00	2000.	450.		11
11	172.00	78.00	10000.	450.	1003	10
12	145.00	75.00	30000.	400.	1002	10
13	60.00	60.00	30000.	400.	1001	10
14	25.00	25.00	30000.	400.		
15	0.00	0.00	0.	150.		10 3 7

TARGET 1 LOCATION - X= 175.0 Y= 75.0
FP COMMAND
--

FIGURE 25. SAMPLE OPERATION OF THE INTERACTIVE PROCESSOR
(Continued)

- (9) A complete user's manual is available on-line in addition to the question mark feature. It can be entered from anywhere in the interactive program. The user must then indicate which section and subsection (and paragraph, if required) of the manual is desired.
- (10) The user has selected FP Section, C Subsection.
- (11) The text is interrupted periodically to allow the user to exit the manual. When the user exits, the processor returns to the point of entry.

Data Storage

Storage and retrieval procedures for the hardware and function data have been completely revised to provide a more convenient format for the user. The AEP level commands to access these two areas are EQUIP to select hardware data and FUN to select function data. Table 6 lists the set of data manipulation commands available for these two areas.

Figure 26 shows an example of some of equipment data access commands which are described as follows:

- (1) Display list of available equipment sections
- (2) Select propulsion system section
- (3) Display available propulsion candidates, the command request indicates to the user that he has already selected section 23.
- (4) Select first candidate
- (5) Display data associated with this candidate
- (6) Change value of MTBMA
- (7) Partial display of data

Figure 27 shows an example of some of the function commands which are described as follows

- (1) Display list of available functions
- (2) Select Weapon Delivery function

TABLE 6. EQUIP/FUNCT COMMANDS

Command	Description
LIST	Display items accessible at current level
SELECT	Choose one of items available at current level
CREATE	Create a new data record at the candidate or mode level
DELETE	Delete a data record at the candidate or mode level
NAME	Assign an alphanumeric label to a data record
DATA	Enter data values for a record
SHOW	Display data values for current record
RANGE	Display data range limits
SAVE	Make a permanent entry into the data base for the current record
QUIT	Return to the top EQUIP (FUN) level

(1) EQUIPMENT COMMAND
-- LIST

ID	SECTION
11	AIRFRAME
12	COCKPIT AND FUSELAGE COMPARTMENT
13	LANDING GEAR
14	FLIGHT CONTROLS
23	PROPULSION SYSTEM
24	SECONDARY POWER SYSTEM
41	AIR-CONDITIONING, PRESSURIZATION AND SURFACE ICE
42	ELECTRICAL POWER SUPPLY
44	LIGHTING SYSTEMS
45	HYDRAULIC AND PNEUMATIC POWER SUPPLY
46	FUEL SYSTEM
47	OXYGEN SYSTEM
49	MISCELLANEOUS UTILITIES
51	INSTRUMENTS
52	AUTOPILOT
55	MAJFUNCTION ANALYSIS AND RECORDING EQUIPMENT
57	INTEGRATED GUIDANCE AND FLIGHT CONTROL
62	VHF COMMUNICATIONS
63	UHF COMMUNICATIONS
64	INTERPHONE
65	IFF
69	INTEGRATED COMM/NAVIGATION/IFF PACKAGE
71	RADIO NAVIGATION
72	RADAR NAVIGATION
73	BOMBING NAVIGATION
74	FIRE CONTROL
75	WEAPON DELIVERY
76	ELECTRONIC COUNTERMEASURE (TACTICAL WARFARE)
77	PHOTOGRAPHIC/RECONNAISSANCE
91	EMERGENCY EQUIPMENT
92	TOW-TARGET EQUIPMENT
93	DRAG CHUTE EQUIPMENT
96	PERSONNEL AND MISC EQUIPMENT
97	EXPLOSIVE DEVICES AND COMPONENTS

- EQUIPMENT COMMAND
- (2) -- SELECT, 23
SECTION 23 COMMAND
- (3) -- LIST
ID CAND FOR PROPULSION SYSTEM
1 PROPULSION CANDIDATE
SECTION 23 COMMAND
- (4) -- SELECT, 1

FIGURE 26. EXAMPLE OF EQUIPMENT COMMANDS

(5) SECTION 23 COMMAND
 -- SHOW

ITEM	DATA VARIABLE	VALUE
1	MTBF (FLIGHT HOURS)	5.
2	MTBMA (HOURS)	8.
3	OPERATIONAL/FLIGHT HOUR RATIO	2.
4	VULNERABILITY	.1
5	NUMBER OF REDUNDANT BOXES	0.
6	MTTR (HOURS)	.5
7	PROBABILITY OF REPLACEMENT	.9
8	PROBABILITY ITEM AVAILABLE	.9
9	PROBABILITY OF UNDETECTED FAILURE	.1
10	PROBABILITY OF FALSE FAILURE	.1
11	ACQUISITION COST (\$K)	100000.
12	COST PER MAINTENANCE ACTION (\$)	500.
13	MIL SPEC IMP (HRS)	.84
14	MAX SPEC IMP (HRS)	1.97
15	MIL THRUST (LB)	11870.
16	MAX THRUST (LB)	17900.

(6) SECTION 23 COMMAND
 -- DATA, X2, 25

(7) SECTION 23 COMMAND
 -- SHOW, 1, 3

ITEM	DATA VARIABLE	VALUE
1	MTBF (FLIGHT HOURS)	5.
2	MTBMA (HOURS)	25.
3	OPERATIONAL/FLIGHT HOUR RATIO	2.

FIGURE 26. EXAMPLE OF EQUIPMENT COMMANDS (Continued)

```

(1)  FUNCTION COMMAND
      -- LIST
      ID  FUNCTION
        1  SCHEDULED MAINTENANCE
        2  ORDNANCE
        3  FUEL
        4  FLIGHT
        5  MISSION
        6  FORMATION
        7  NAVIGATION
        8  NAVIGATION UPDATE
        9  COMMUNICATIONS
       10  SURVIVABILITY
       11  TARGET ACQUISITION
       12  WEAPON DELIVERY
       13  TARGET
      FUNCTION COMMAND
(2)  -- SELECT,12
      FUNCTION 12 COMMAND
(3)  -- LIST
      ID  SUBFUNCTION
        1  UNGUIDED MANUAL WEAPON DELIVERY
        2  UNGUIDED AUTOMATIC WEAPON DELIVERY
      FUNCTION 12 COMMAND
(4)  -- SELECT,2
      SUBFUNCTION 12,2 COMMAND
(5)  -- CREATE
      SUBFUNCTION 12,2 COMMAND
(6)  -- DATA,X1,5000,4,100,20,50,1,2,2
      SUBFUNCTION 12,2 COMMAND
(7)  -- SHOW
      ITEM  DATA VARIABLE
        1  WEAPON RELEASE DISTANCE (FT)
        2  SET-UP TIME (SEC)
        3  AIM POINT CEP
        4  PRIMARY KILL RADIUS (FT)
        5  SECONDARY KILL RADIUS (FT)
        6  ORDNANCE SUBFUNCTION TYPE
        7  NUMBER DROPPED PER PASS
        8  PACKED TARGET INDICES
      SUBFUNCTION 12,2 COMMAND
(8)  -- NAME,NEW WEAPON DELIVERY MODE
      SUBFUNCTION 12,2 COMMAND
(9)  -- SAVE
      SUBFUNCTION 12,2 COMMAND
(10) -- LIST
      ID  MODE FOR UNGUIDED AUTOMATIC WEAPON DELIVERY
        1  AUTOMATIC MODE 1
        2  NEW WEAPON DELIVERY MODE

```

	VALUE
1	5000.
2	4.
3	100.
4	20.
5	50.
6	1.
7	2.
8	2.

FIGURE 27. EXAMPLE OF FUNCTION COMMANDS

- (3) Display Weapon Delivery Subfunctions
- (4) Select Automatic Weapon Delivery subfunction
- (5) Create a new mode
- (6) Enter data for mode
- (7) Display the data
- (8) Assign a title to the new data record
- (9) Make a permanent entry for the new data
- (10) List of modes now stored for subfunction 11, 2

Output Display

The interactive output processor has been revised to give the user control over what results to display. Table 7 lists the commands available for output processing. Figure 28 shows an example of two of the commands. A complete detailed output is given in Appendix A.

TABLE 7. OUTPUT COMMANDS

Command	Description
TITLE	Display title associated with execution, number of days simulated, and number of Monte Carlo samples
EQUIP	List aircraft hardware names
STAT,ID	Display statistics for random variables ID = GND for ground based variables = AIR for airborne variables = COST for cost accumulations = ALL for all of above variables

TABLE 7. OUTPUT COMMANDS (Continued)

Command	Description
EVENTS, ID	Display output for occurrence of events, ID used as above
FAIL	List failures by equipment item
SUBF	List subfunction/mode utilization
LEVEL	Select level of detail, either an aggregated output or a breakdown by aircraft and targets

AEPOUT COMMAND
 -- STAT,GND

GROUND PREPARATION DATA

VARIABLE	SAMPLES	MEAN	STD DEV	MAX	MIN
SORTIES PER DAY	50	2.56	.541	3.00	1.00
PREFLIGHT TIME (HR)	100	3.03	.579	5.13	1.93
THRU-FLIGHT TIME (HR)	191	2.00	.501	3.83	1.10
POSTFLIGHT TIME (HR)	100	4.88	.942	8.07	2.84
LAUNCH (MIN)	129	15.0	5.30	31.9	6.20
LAUNCH DELAY (MIN)	96	42.9	28.8	119.	2.18
REPAIR DELAY (MIN)	103	29.4	11.4	77.5	12.3
MAINTENANCE ACTIONS (MIN)	120	28.4	9.41	77.5	12.3
FUEL LOADING TIME (MIN)	290	5.72	2.67	14.7	1.63
FUEL LOADED (LB)	290	2861.	1335.	7336.	816.
G.P. MUNITIONS LOAD (MIN)	289	19.5	4.10	31.4	4.29
G.P. MUNITIONS DEARM(MIN)	47	9.98	3.34	14.9	3.68

AEPOUT COMMAND
 -- EVENTS,AIR

-----AIRBORNE EVENTS-----

DETECTED FAILURE	129
FALSE FAILURE	9
UNDETECTED FAILURE	10
AIRCRAFT ABORT	1
AIRCRAFT LOST	38
A/C LOST TO ENEMY FIRE	9
MISSION ABORT	5
LOW FUEL ABORT	0
DISPLAY TARGET DETECTION	116
VISUAL TARGET DETECTION	132
TARGET ATTACKED	248
PRIMARY DESTRUCTION	20
SECONDARY DESTRUCTION	88
GO-AROUND FOR ATTACK	6

FIGURE 28. SAMPLE OUTPUT COMMANDS

APPENDIX A

SAMPLE EXECUTION OF THE AEP

APPENDIX A

SAMPLE EXECUTION OF THE AEP

This purpose of this appendix is to describe a sample execution of the AEP. For this demonstration, a fairly simple mission is simulated. Figure A-1 shows the waypoints for the flight profile. Each waypoint has an X and Y position (nautical miles), altitude (ft) and velocity (knots). In addition, functions and subfunctions are turned on and off.

Four hardware items were selected for each of two aircraft: (1) an airframe, (2) propulsion system, (3) ordnance, and (4) acquisition display. Figure A-2 shows the data used for these items. Figure A-3 shows the data used for selected subfunctions.

Figure A-4 shows a detailed list of the output results. The simulation consisted of 25 Monte Carlo trials using two aircraft for 2 days.

ID	X	Y	H	V	ON	OFF
1	0.00	0.00	0.	300.	302 601 701 901 902	
2	10.00	0.00	10000.	300.		
3	20.00	0.00	10000.	500.	702 801 1001 1101 1102	
4	200.00	0.00	10000.	500.	303	
5	200.00	20.00	10000.	500.		11
6	0.00	0.00	10000.	500.		

TARGET 1 LOCATION -	X=	190.0	Y=	0.0
TARGET 2 LOCATION -	X=	200.0	Y=	10.0

FIGURE A-1. FLIGHT PROFILE DESCRIPTION

ITEM	DATA VARIABLE	VALUE
1	MTBF (FLIGHT HOURS)	35.
2	MTBMA (HOURS)	8.
3	OPERATIONAL/FLIGHT HOUR RATIO	2.
4	VULNERABILITY	.1
5	NUMBER OF REDUNDANT BOXES	0.
6	MTTR (HOURS)	.5
7	PROBABILITY OF REPLACEMENT	.9
8	PROBABILITY ITEM AVAILABLE	.9
9	PROBABILITY OF UNDETECTED FAILURE	.1
10	PROBABILITY OF FALSE FAILURE	.1
11	ACQUISITION COST (\$K)	100000.
12	COST PER MAINTENANCE ACTION (\$)	500.
13	WEIGHT (LBS)	32834.
14	EXTERNAL FUEL (LBS)	0.
15	INTERNAL FUEL (LBS)	12058.
16	MEAN AERO CHORD (FT)	16.04
17	WING AREA (SQ FT)	530.
18	CL-ALFA (TAKEOFF)	3.6
19	CL-ALFA (SUBSONIC)	3.6
20	CL-ALFA (TRANSONIC)	4.5
21	CL-ALFA (SUPERSONIC)	2.8
22	CL-DELTA (TAKEOFF)	.63
23	CL-DELTA (SUBSONIC)	.6
24	CL-DELTA (TRANSONIC)	.45
25	CL-DELTA (SUPERSONIC)	.34
26	CM-ALFA (TAKEOFF)	-.2
27	CM-ALFA (SUBSONIC)	-.2
28	CM-ALFA (TRANSONIC)	-.6
29	CM-ALFA (SUPERSONIC)	-.6
30	CM-DELTA (TAKEOFF)	-.9
31	CM-DELTA (SUBSONIC)	-.8
32	CM-DELTA (TRANSONIC)	-.7
33	CM-DELTA (SUPERSONIC)	-.4
34	CM-Q (TAKEOFF)	-3.7
35	CM-Q (SUBSONIC)	-3.2
36	CM-Q (TRANSONIC)	-4.5
37	CM-Q (SUPERSONIC)	-2.5
38	CD-ZERO (TAKEOFF)	.02
39	CD-ZERO (SUBSONIC)	.02
40	CD-ZERO (TRANSONIC)	.038
41	CD-ZERO (SUPERSONIC)	.043
42	ALFA-ZL (TAKEOFF)	-.008
43	ALFA-ZL (SUBSONIC)	-.008
44	ALFA-ZL (TRANSONIC)	-.008
45	ALFA-ZL (SUPERSONIC)	0.
46	D2 (TAKEOFF)	.1215
47	D2 (SUBSONIC)	.1215
48	D2 (TRANSONIC)	.1497
49	D2 (SUPERSONIC)	.4687
50	D4 (TAKEOFF)	.0873
51	D4 (SUBSONIC)	.0873
52	D4 (TRANSONIC)	.00794
53	D4 (SUPERSONIC)	.1563
54	ALFA-MAX (TAKEOFF)	13.5
55	ALFA-MAX (SUBSONIC)	18.
56	ALFA-MAX (TRANSONIC)	24.
57	ALFA (SUPERSONIC)	24.
58	CM-ZERO	-.01
59	CD-ZERO DRAG BRAKE	0.

(a) AIRFRAME

FIGURE A-2. SAMPLE HARDWARE DATA

ITEM	DATA VARIABLE	VALUE
1	MTBF (FLIGHT HOURS)	5.
2	MTBMA (HOURS)	8.
3	OPERATIONAL/FLIGHT HOUR RATIO	2.
4	VULNERABILITY	.1
5	NUMBER OF REDUNDANT BOXES	0.
6	MTTR (HOURS)	.5
7	PROBABILITY OF REPLACEMENT	.9
8	PROBABILITY ITEM AVAILABLE	.9
9	PROBABILITY OF UNDETECTED FAILURE	.1
10	PROBABILITY OF FALSE FAILURE	.1
11	ACQUISITION COST (\$K)	100000.
12	COST PER MAINTENANCE ACTION (\$)	500.
13	MIL SPEC IMP (HRS)	.84
14	MAX SPEC IMP (HRS)	1.97
15	MIL THRUST (LB)	11870.
16	MAX THRUST (LB)	17900.

(b) PROPULSION SYSTEM

ITEM	DATA VARIABLE	VALUE
1	MTBF (FLIGHT HOURS)	0.
2	MTBMA (HOURS)	0.
3	OPERATIONAL/FLIGHT HOUR RATIO	0.
4	VULNERABILITY	0.
5	NUMBER OF REDUNDANT BOXES	0.
6	MITR (HOURS)	0.
7	PROBABILITY OF REPLACEMENT	0.
8	PROBABILITY ITEM AVAILABLE	0.
9	PROBABILITY OF UNDETECTED FAILURE	0.
10	PROBABILITY OF FALSE FAILURE	0.
11	ACQUISITION COST (\$K)	500.
12	COST PER MAINTENANCE ACTION (\$)	0.

(c) ORDNANCE

ITEM	DATA VARIABLE	VALUE
1	MTBF (FLIGHT HOURS)	5.
2	MTBMA (HOURS)	8.
3	OPERATIONAL/FLIGHT HOUR RATIO	2.
4	VULNERABILITY	.1
5	NUMBER OF REDUNDANT BOXES	1.
6	MTTR (HOURS)	.5
7	PROBABILITY OF REPLACEMENT	.9
8	PROBABILITY ITEM AVAILABLE	.9
9	PROBABILITY OF UNDETECTED FAILURE	.1
10	PROBABILITY OF FALSE FAILURE	.1
11	ACQUISITION COST (\$K)	100000.
12	COST PER MAINTENANCE ACTION (\$)	500.

(d) ACQUISITION DISPLAY

FIGURE A-2. SAMPLE HARDWARE DATA (Continued)

ITEM	DATA VARIABLE	VALUE
1	EARLIEST TIME TO BEGIN PREFLIGHT (HR)	6.
2	EARLIEST TIME TO BEGIN LAUNCH (HR)	9.
3	MINIMUM TIME UNTIL NEXT SORTIE (HR)	4.
4	LATEST TIME TO LAUNCH SORTIE (HR)	18.
5	MAXIMUM DELAY BEFORE CANCEL (HR)	2.
6	NUMBER OF DAYS TO SIMULATE	2.

(a) SCHEDULE

ITEM	DATA VARIABLE	VALUE
1	NUMBER OF AIRCRAFT PER SQUADRON	16.
2	FUEL COST (\$/LB)	1.
3	PER FLIGHT COST (\$)	5000.
4	PER UNIT OF FLIGHT TIME COST (\$/FLIGHT-HR)	500.
5	FLIGHT CREW SIZE	10.
6	FLIGHT CREW COST (\$/MAN-YEAR)	5000.
7	GROUND CREW SIZE	20.
8	GROUND CREW COST (\$/MAN-YEAR)	6000.
9	MUNITIONS CREW SIZE	10.
10	MUNITIONS CREW COST (\$/MAN-YEAR)	7000.
11	COMMAND STAFF SIZE	5.
12	COMMAND STAFF COST (\$/MAN-YEAR)	15000.
13	NUMBER OF ADDITIONAL PERSONNEL	50.
14	ADDITIONAL PERSONNEL COST (\$/MAN-YEAR)	6000.
15	INVESTMENT PECULIAR TO SYSTEM (\$)	1.00E 6
16	AMORITIZATION PERIOD (YEARS)	5.

(b) COST

ITEM	DATA VARIABLE	VALUE
1	HORIZONTAL WIDTH OF FIELD OF VIEW (DEG)	90.
2	SIDE LOOK ANGLE A/C 1 (DEG)	45.
3	SIDE LOOK ANGLE A/C 2 (DEG)	-45.
4	SIDE LOOK ANGLE A/C 3 (DEG)	0.
5	SIDE LOOK ANGLE A/C 4 (DEG)	0.
6	DEPRESSION ANGLE (DEG)	10.
7	CUMULATIVE PROBABILITY OF DETECTION	0.
8	DEPRESSION ANGLE (DEG)	30.
9	CUMULATIVE PROBABILITY OF DETECTION	.5
10	DEPRESSION ANGLE (DEG)	0.
11	CUMULATIVE PROBABILITY OF DETECTION	0.
12	DEPRESSION ANGLE (DEG)	0.
13	CUMULATIVE PROBABILITY OF DETECTION	0.
14	DEPRESSION ANGLE (DEG)	0.
15	CUMULATIVE PROBABILITY OF DETECTION	0.

(c) VISUAL ACQUISITION

FIGURE A-3. SAMPLE SUBFUNCTION DATA

ITEM	DATA VARIABLE	VALUE
1	WEAPON RELEASE DISTANCE (FT)	5000.
2	SET-UP TIME (SEC)	4.
3	AIM POINT CEP	100.
4	PRIMARY KILL RADIUS (FT)	20.
5	SECONDARY KILL RADIUS (FT)	50.
6	ORDNANCE SUBFUNCTION TYPE	1.
7	NUMBER DROPPED PER PASS	2.
8	PACKED TARGET INDICES	1.

(d) MANUAL WEAPON DELIVERY

ITEM	DATA VARIABLE	VALUE
1	NUMBER OF ATTACK PASSES	1.
2	X LOCATION UNCERTAINTY (NM)	1.
3	Y LOCATION UNCERTAINTY (NM)	1.

(e) TARGET

FIGURE A-3. SAMPLE SUBFUNCTION DATA (Continued)

DEMONSTRATION CASE FOR NEW VERSION OF AEP

25 MONTE CARLO TRIALS, WITH 2 AIRCRAFT, FOR , 2 DAYS

AEP OUT COMMAND
-- STAT, ALL

GROUND PREPARATION DATA

VARIABLE	SAMPLES	MEAN	STD DEV	MAX	MIN
SORTIES PER DAY	50	2.56	.541	3.00	1.00
PREFLIGHT TIME (HR)	100	3.03	.579	5.13	1.93
THRU-FLIGHT TIME (HR)	191	2.00	.501	3.83	1.10
POSTFLIGHT TIME (HR)	100	4.88	.942	8.07	2.84
LAUNCH (MIN)	129	15.0	5.30	31.9	6.20
LAUNCH DELAY (MIN)	96	42.9	28.8	119.	2.18
REPAIR DELAY (MIN)	103	29.4	11.4	77.5	2.3
MAINTENANCE ACTIONS (MIN)	120	28.4	9.41	77.5	12.3
FUEL LOADING TIME (MIN)	290	5.72	2.67	14.7	1.63
FUEL LOADED (LB)	290	2861.	1335.	7336.	816.
G.P. MUNITIONS LOAD (MIN)					
A/C	145	19.9	4.10	31.4	4.29
A/C 2	144	19.1	4.09	29.6	6.83
G.P. MUNITIONS DEARM(MIN)					
A/C 1	24	9.99	3.83	14.9	3.68
A/C 2	23	9.96	2.83	14.2	4.57

AIRBORNE DATA

VARIABLE	SAMPLES	MEAN	STD DEV	MAX	MIN
AIR REFUELING TIME (MIN)	123	15.2	3.78	21.1	5.60
AIRBORNE FUEL ADDED (LB)	237	5208.	689.	6555.	4260.
DISPLAY DETECTION RNG(NM)					
A/C 1	54	3.25	.893	5.06	1.93
A/C 2	62	3.44	.847	5.16	1.98
VISUAL DETECTION RNG(NM)					
A/C 1	76	5.31	1.52	9.35	3.27
A/C 2	56	5.99	1.80	9.95	3.46
NAV UPDATE ACCURACY (FT)	127	59.5	617.	1954.	-1544.
NUMBER OF ATTACK PASSES					
TARGET 1	127	1.00	0.	1.00	1.00
TARGET 2	121	1.00	0.	1.00	1.00

FIGURE A-4. OUTPUT RESULTS

COST DATA

VARIABLE	SAMPLES	MEAN	STD DEV	MAX	MIN
FUEL COST (\$)					
A/C 1	25	39520.	7562.	51332.	21274.
A/C 2	25	42798.	10920.	67719.	27317.
G.P. MUNITIONS COST (\$)					
A/C 1	25	9960.	1744.	12000.	6000.
A/C 2	25	9960.	1881.	12000.	6000.
MAINTENANCE COST (\$)					
A/C 1	25	1300.	804.	2500.	0.
A/C 2	25	1100.	707.	3000.	0.
REPLACEMENT COST (\$)					
A/C 1	25	408260.	227449.	801000.	100000.
A/C 2	25	556500.	349309.	1.41E 6	100000.
TOTAL DIRECT A/C COST (\$)					
A/C 1	25	459040.	230173.	855040.	144726.
A/C 2	25	610358.	358307.	1.49E 6	135817.
FLIGHT COSTS (\$)	25	55618.	9591.	65528.	32551.
FLIGHT CREW COST (\$)	25	34.2	0.	34.2	34.2
GROUND CREW COST (\$)	25	82.2	0.	82.2	82.2
MUNITIONS CREW COST (\$)	25	47.9	0.	47.9	47.9
COMMAND STAFF COST (\$)	25	51.4	0.	51.4	51.4
MISC. PERSONNEL COST (\$)	25	205.	0.	205.	205.
AMORTIZATION COST (\$K)	25	18250.	0.	18250.	18250.
TOTAL MISSION COST(\$K)	25	19375.	407.	20560.	18767.

FIGURE A-4. OUTPUT RESULTS (Continued)

AEFOUT COMMAND
-- EVENTS, ALL

-----GROUND EVENTS-----
GENERAL MAINTENANCE 19
SORTIE CANCELLED 3
NOT OPERATIONALLY READY 5
EQUIPMENT ITEM REPLACED 89
REPLACEMENT UNAVAILABLE 15

-----AIRBORNE EVENTS-----
DETECTED FAILURE 129
FALSE FAILURE 9
UNDETECTED FAILURE 10
AIRCRAFT ABORT
 A/C 1 0
 A/C 2 1
AIRCRAFT LOST
 A/C 1 13
 A/C 2 25
A/C LOST TO ENEMY FIRE
 A/C 1 5
 A/C 2 4
MISSION ABORT 5
LOW FUEL ABORT 0
DISPLAY TARGET DETECTION
 A/C 1 54
 A/C 2 62
VISUAL TARGET DETECTION
 A/C 1 73
 A/C 2 59
TARGET ATTACKED
 TARGET 1 127
 TARGET 2 121
PRIMARY DESTRUCTION
 TARGET 1 10
 TARGET 2 10
SECONDARY DESTRUCTION
 TARGET 1 49
 TARGET 2 39
GO-AROUND FOR ATTACK
 TARGET 1 1
 TARGET 2 5

FIGURE A-4. OUTPUT RESULTS (Continued)

SUBFUNCTION/MODE UTILIZATION

SUBFUNCTION	NO. USES	FAILED	MODES (1-N)		
PREFLIGHT	50	0	0		
THRU-FLIGHT	96	0	0		
POSTFLIGHT	50	0	0		
G.P. MUNITIONS	289	0	0		
FUEL LOADING	290	0	0		
BINGO FUEL	129	0	129		
REFUELING	128	0	128		
LAUNCH	129	1	129		
INFLIGHT ABORT	128	0	128		
MISSION ABORT	128	0	128		
AIRCRAFT LOST	128	0	128		
LANDING	128	0	128		
SCHEDULE	50	0	0		
RADIO-AIDED NAV	129	0	129		
SELF-CONTAINED NAV	128	0	128		
AUTO-NAV UPDATE	128	0	128		
INTER-FLIGHT COM.	129	0	129		
EXTERNAL COM.	129	0	129		
SURVIVABILITY	128	0	128		
DISPLAY ACQUISITION	128	0	128		
VISUAL ACQUISITION	128	0	128		
MANUAL WEAPON DEL. A/C 1	121	0	104	9	21
MANUAL WEAPON DEL. A/C 2	115	1	104	9	10
AUTOMATIC WEAPON DEL A/C 1	100	0	100		
AUTOMATIC WEAPON DEL A/C 2	100	0	100		

FIGURE A-4. OUTPUT RESULTS (Continued)

AEPOUT COMMAND
-- FAIL

EQUIPMENT FAILURES PER A/C

ITEM	AIRCRAFT	GROUND	AIRBORNE
AIRFRAME	A/C 1	4	7
	A/C 2	7	3
PROPULSION	A/C 1	15	8
	A/C 2	15	19
ORDNANCE	A/C 1	0	0
	A/C 2	0	0
RADAR	A/C 1	20	27
	A/C 2	21	21

FIGURE A-4. OUTPUT RESULTS (Continued)

APPENDIX B

PROGRAMMER'S GUIDE

APPENDIX B

PROGRAMMER'S GUIDE

The purpose of this Appendix is to provide a description of the Avionics Evaluation Program (AEP) Computer Code. The following references can also be consulted:

- (1) "Avionics Evaluation Program User's Manual",
Battelle-Columbus Laboratories (most recent version)
- (2) "Application of Interactive Graphics to the Avionics
Evaluation Program", Battelle-Columbus Laboratories,
Programmer's Manual (most recent version).

The first reference is the user's manual which resides in the computer and is accessible from a terminal. The second describes the interactive graphics processor from which the AEP is operated.

Figure B-1 shows the Avionics Evaluation Program (AEP) organization. There are two major overlays. The first contains the computations carried out in preparation for the Monte Carlo analysis. The second contains the Monte Carlo simulation. Table B-1 contains a brief description of each of the program subroutines. In addition, the table shows where each subroutine occurs. Table B-2 defines where each common block occurs. The bulk of the code documentation resides in the program itself. At the beginning of the routines is a description of the purpose of the routine and a definition of the parameters in the calling list. In addition, all common variables are described in each routine where they are used.

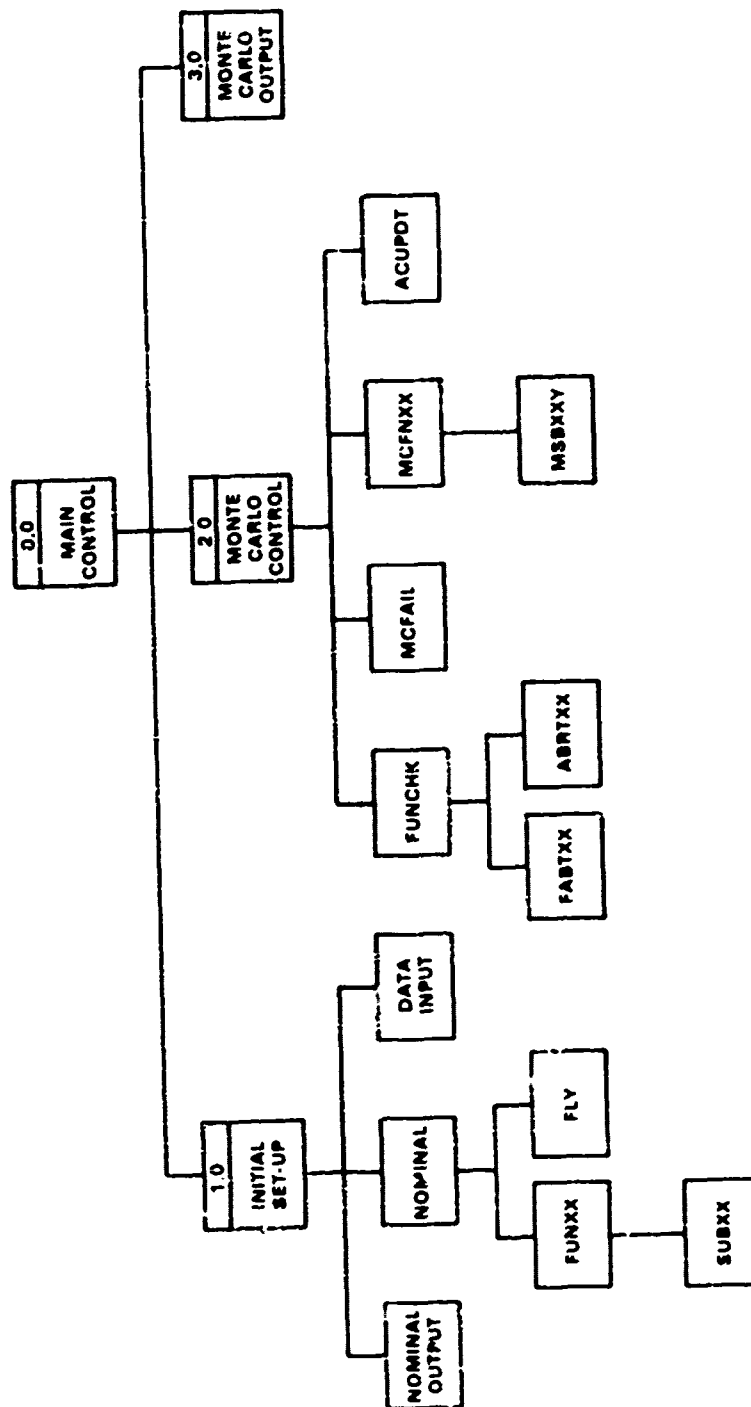


FIGURE B-1. AEP ORGANIZATION

TABLE B-1. DESCRIPTION OF THE BATCH AEP ROUTINES

Routine Name	Category	Description
MAIN	EXECUTION	Calls Individual Overlays
COMBLK	DATA	Initialize variables in labelled common
ONE	EXECUTION	Calls routines to evaluate nominal mission
CMBLK1	DATA	Initialize variables in labelled common
ONEONE	EXECUTION	Calls routine to read mission input data and write system labels to random access file
TWO	EXECUTION	Calls Monte Carlo main control routine
THREE	EXECUTION	Calls the output routines
READ	DATA	Read data from random access file
WRITE	DATA	Write data to random access file
GENFLE	DATA	Routine to create a random access file
CLSFLE	DATA	Routine to close a random access file
NEWFLE	DATA	Routine to open a new random access file
ENDJOB	ERROR PROCESSING	Routine to insure complete writing of data to random access file if execution error occurs
IDLE	UTILITY	Routine to set file status to idle to avoid auto-recall errors
INDXSEQ	DATA	Machine language routine to access files
SETADR	UTILITY	Routine to convert the FORTRAN extended parameter list to a RUN compatible parameter list
ADDSUB	UTILITY	Add or subtract matrices

TABLE B-1. DESCRIPTION OF THE BATCH AEP ROUTINES (Continued)

Routine Name	Category	Description
TRANS	UTILITY	Transpose a matrix
PACK	UTILITY	Create an array of the upper triangle of a symmetric matrix
UNPACK	UTILITY	Restore symmetric matrix from packed array
MOVE	UTILITY	Transfer matrix to new memory location
MINUS	UTILITY	Transfer negative of matrix to new-memory location
ZERO	UTILITY	Set matrix to zero
TADSUB	UTILITY	Transpose matrix addition or subtraction
CONST	UTILITY	Scalar times a matrix
MLT	UTILITY	Matrix multiplication
SYMMLT	UTILITY	Symmetric matrix multiplication
MLTADSU	UTILITY	Transpose matrix multiplication
CROSS	UTILITY	Vector cross product
DOT	UTILITY	Vector dot product
IRKG	UTILITY	Initializes certain variables for the Runge-Kutta-Gill integration routine. Standard BCL library routine.
RKG	UTILITY	Runge-Kutta-Gill integration routine. Standard BCL library routine.
BILIN1	UTILITY	Interpolates on a two dimensional table. Both arguments must be monotone increasing. Standard BCL library routine.

TABLE B-1. DESCRIPTION OF THE BATCH AEP ROUTINES (Continued)

Routine Name	Category	Description
SETCON	UTILITY	Set natural constants, conversion factors
PUT	EXECUTION	Enter event in table
TAKE	EXECUTION	Remove event from table
PUTALL	EXECUTION	Put general event for all available subfunctions in event table
GETFND	EXECUTION	Move data from packed arrays to local variables
RESET	EXECUTION	Calls routine RSETXX
SETLAB	DATA	Set labels and units for output variables
NOMINL	EXECUTION	Calls aircraft flight routines and function routines
FLY	EXECUTION	Simulates aircraft flight. Described in AFAL-TR-73-44
CONTRL	EXECUTION	Calculates required aircraft power setting for requested velocity. Described in AFAL-TR-73-44.
DERAC	EXECUTION	Calculates derivatives of aircraft equations of motion. Described in AFAL-TR-73-44.
VARMCH	UTILITY	Interpolates tabular data as a function of mach number. Described in AFAL-TR-73-44.
PRTST	UTILITY	Print aircraft flight status
FUNON	EXECUTION	Make initial calls to function
RSETXX	EXECUTION	Set data values for various modes of each subfunction

TABLE B-1. DESCRIPTION OF THE BATCH AEP ROUTINES (Continued)

Routine Name	Category	Description
FUNXX	EXECUTION	Perform calculations for function XX
MCFNXX	EXECUTION	Contains the Monte Carlo computations for function XX. XX can range from 1-20. Main body of report contains flow diagrams.
MSBXXY	EXECUTION	Contains the Monte Carlo computations for subfunction 1 of function XX. Called by function XX. Main body of report contains flow diagrams.
ABRTXX	EXECUTION	Logic to determine if aircraft aborts when subfunction for function XX is lost by that aircraft.
FABTXX	EXECUTION	Logic to determine if mission aborts when subfunction for function XX is lost by entire flight
NAVPOS	EXECUTION	Routine to calculate current navigation error
NAVUPD	EXECUTION	Performs navigation update. Calculates sensor field of view. Determines if checkpoint is within the sensor field of view and if the checkpoint has been detected.
DAMAGE	EXECUTION	Determine extent of aircraft damage resulting from enemy hit
SUB111	EXECUTION	Display Acquisition subfunction. Calculates sensor field of view for each mode.
SUB112	EXECUTION	Visual acquisition subfunction. Calculates sensor field of view for each mode.

TABLE B-1. DESCRIPTION OF THE BATCH AEP ROUTINES (Continued)

Routine Name	Category	Description
SENSOR	EXECUTION	Calculates the sensor ground coverage by computing the X and Y vertices of the sensor field of view
ACQUIRE	EXECUTION	Generates target acquisition times based on cumulative probability of detection vs. depression angle and the vertices of the sensor field of view.
SETST	EXECUTION	Calculate aircraft states inertial coordinate frame of reference
SAVEST	EXECUTION	Store aircraft states for use during Monte Carlo evaluation
READAT	DATA	Reads system and function data
CRUISE	DATA	Fits curve for heading in flight profile
PRTMC	EXECUTION	Prints Monte Carlo status during program error tracing
NORM	UTILITY	Generate unit variance normal random variate
F	UTILITY	Used by NORM
LGNORM	UTILITY	Generate a log-normal random variate
BETA	UTILITY	Generate a random variate from a Beta distribution
RAYLGH	UTILITY	Generate a random variate from a Rayleigh distribution
RNDTME	UTILITY	Generate a random variate from a tabular distribution

TABLE B-1. DESCRIPTION OF THE BATCH AEP ROUTINES (Continued)

Random Name	Category	Description
SETVAR	EXECUTION	Accumulate statistics for random variables
SETEVT	EXECUTION	Accumulate occurrences of random events
MCARLO	EXECUTION	Monte Carlo simulation main control program
MCINTL	EXECUTION	Initialize Monte Carlo variables
ACUPDT	EXECUTION	Update aircraft states as a function of time
MCFAIL	EXECUTION	Calculate time of equipment failure
CLKON	EXECUTION	Turn flight failure clock on
CLKOFF	EXECUTION	Turn flight failure clock off
FAIL	EXECUTION	Process equipment failures
REPAIR	EXECUTION	Calculate random repair time after equipment failure. Determine operationally ready status of aircraft.
UMAINT	EXECUTION	Calculate unscheduled maintenance delay time. Determine operationally ready status of aircraft.
FUNCHK	EXECUTION	Check subfunction modes after equipment failure
MCFON	EXECUTION	Turn on subfunction
USE	EXECUTION	Check for undetected failures when a subfunction is used

TABLE B-1. DESCRIPTION OF THE BATCH AEP ROUTINES (Continued)

Random Name	Category	Description
ACABRT	EXECUTION	Call aircraft abort routines
ACLOST	EXECUTION	Call required routines when aircraft is lost from flight
MISABT	EXECUTION	Abort mission
FNABRT	EXECUTION	Calls mission abort routines
RESULT	OUTPUT	Prints Monte Carlo results (3 levels of detail) for each flight
CONVRT	UTILITY	Converts real numbers to F type format if possible, otherwise uses E type format
ITOB CD	UTILITY	Converts integer numbers to alpha-numeric representation
RTOB CD	UTILITY	Converts real numbers to alphanumeric representation
GETDIG	UTILITY	Converts integer numbers to an array of BCD characters representing the integer
NEWAC	EXECUTION	Initialize aircraft variables for an aircraft lost during previous sortie
CANCEL	EXECUTION	Cancels rest of day to allow simulation to proceed to next day

TABLE B-2. AEP COMMON BLOCKS

COMMON BLOCK	ROUTINES USING THE COMMON BLOCK
ABTFLG	MISABT, MSB041
ACRAFT	CMBLK1, CONTRL, CRUISE, DERAC, FLY, PRTST, READAT, SAVEST, SETST
AIRCFT	CMBLK1, CONTRL, DERAC, FLY, READAT
ATTACK	ABRT12, ACUPDT, MCFN0N, MCFN12, MCFN13, MSB111, MSB122
AVAIL	MCAULO, REPAIR
CMS011	MSB011, RSET01
CMS012	MSB012, RSET01
CMS013	MSB013, RSET01
CMS021	MSB021, RSET02
CMS022	MSB022, RSET02
CMS023	MSB023, RSET02
CMS031	MSB031, RSET03
CMS032	MSB032, RSET03
CMS033	MSB033, RSET03
CMS041	MSB041, RSET04
CMS051	MCARLO, MSB051, RSET05
CMS052	MSB052, RSET05
CMS061	RSET06, SETST
CMS071	MSB071, RSET07
CMS072	MSB072, RSET07
CMS081	MSB081, RSET08
CMS082	MSB082, RSET08

TABLE B-2. AEP COMMON BLOCKS

COMMON BLOCK	ROUTINES USING THE COMMON BLOCK
CMS083	MSB083, RSET08
CMS091	RSET09
CMS092	RSET09
CMS101	MSB101, RSET10
CMS102	MSB102, RSET10
CMS103	MSB103, RSET10
CMS104	MSB104, RSET10
CMS105	MSB105, RSET10
CMS111	MSB111, RSET11, SUB111
CMS112	MSB112, RSET11, SUB112
CMS121	FUN12, MCFN12, MSB121, RSET12
CMS122	MSB122, RSET12
CMS131	MCFN13, RSET13
CMS132	MCFN13, RSET13
CMS133	MCFN13, RSET13
CMS134	MCFN13, RSET13
CMS135	MCFN13, RSET13
COMPT	SETCON
CONSTS	COMBLK, CONTRL, CRUISE, DERAC, FLY, PRPMC, PRTST, RAYLGH, READAT, RSET07, RSET08, RSET11, RSET12, RSET13, SETCON, SETST
DEBUG	MCARLO, READ, WRITE
DETECT	ACQUIRE, MCFN11, MSB111, MSB112
EQFAIL	ACUPDT, COMBLK, FAIL, MCFAIL, MCINTL, MSB041, MSB045, RESULT, SETCON
EVENTS	ABRT03, ABRT04, ABRT09, ABRT12, ACABRT, ACLOST, ACQUIRE, ACUPDT, CANCEL, CLKOFF, CLKON, COMBLK, FABT03, FABT04, FABT07, FABT09, FABT10, FABT11, FABT12, FAIL,

(Continued on next page)

TABLE B-2. AEP COMMON BLOCKS (Continued)

COMMON BLOCK	ROUTINES USING THE COMMON BLOCK
EVENTS (Continued)	FNABRT, FUNCHK, FUN11, FUN12, MCARLO, MCFN01, MCFN02, MCFN03, MCFN04, MCFN05, MCFN07, MCFN08, MCFN09, MCFN10, MCFN11, MCFN12, MCFN13, MCINTL, MISABT, MSB011, MSB012, MSB013, MSB021, MSB022, MSB023, MSB031, MSB032, MSB033, MSB041, MSB045, MSB051, MSB071, MSB072, MSB081, MSB082, MSB083, MSB091, MSB092, MSB101, MSB102, MSB103, MSB104, MSB105, MSB111, MSB112, MSB121, MSB122, NAVUPD, NEWAC, NOMINL, PRIMC, PUTALL, PUT, SENSOR, SUB111, SUB112, TAKE, UMAINT
FETS	CLSFLE, COMBLK, GENFLE, NEWFLE, READ, WRITE
FETZZZ	CLSFLE, COMBLK, GENFLE, NEWFLE, READ, WRITE
FILES	ACUPDT, CLSFLE, COMBLK, CONTRL, ENDJOB, FLY, GENFLE, MCARLO, MSB111, MSB112, NEWFLE, NOMINL, ONEONE, ONE, PRIST, PUT, READAT, READ, RESULT, SAVEST, SETCON, SETLAB, TAKE, THREE, WRITE
FNDATA	ABRT12, ACLOST, ACQUIRE, COMBLK, FABT07, FABT11, FABT12, FUNCHK, FUNON, FUN12, GETFND, GETMD, MCARLO, MCFN01, MCFN02, MCFN03, MCFN08, MCFN09, MCFN11, MCFN12, MCFN13, MCINTL, MISABT, MSB011, MSB012, MSB013, MSB021, MSB022, MSB023, MSB041, MSB045, MSB052, MSB111, MSB112, MSB121, MSB122, NAVUPD, NOMINL, PUTALL, READAT, REPAIR, RESULT, RSET12, SETCON, SETST, SUB111, SUB112, UMAINT, USE
FOV	SAVEST, SUB111, SUB112
FUEL	ACUPDT, COMBLK, MCARLO, MSB031, MSB033, MSB045, READAT, SETCON

TABLE B-2. AEP COMMON BLOCKS (Continued)

COMMON BLOCK	ROUTINES USING THE COMMON BLOCK
KEYS	ABRT04, COMBLK, FUNCHK, MCARLO, MCFN11, MCINTL, MISABT, MSB041, MSB101, MSB102, MSB103, MSB104, MSB105
LABELS	ONEONE, ONE, READAT
LOCFOV	ACUPDT, COMBLK, FUN11, MSB111, MSB112, SAVEST, SETCON, SUB111, SUB112
MCACFT	ABRT04, ACLOST, ACQUIRE, ACUPDT, COMBLK, DAMAGE, FAPT12, FAIL, FUNCHK, GETMD, MCFAIL, MCFNON, MCFN13, MCINTL, MSB011, MSB012, MSB013, MSB021, MSB022, MSB023, MSB032, MSB033, MSB041, MSB045, MSB101, MSB102, MSB103, MSB104, MSB105, MSB121, MSB122, NEWAC, REPAIR, UMAINT, USE
MCACST	ABRT12, ACLOST, ACQUIRE, COMBLK, FAPT07, FAPT11, FAPT12, FUNCHK, FUNON, FUN12, GETFND, GETMD, MCARLO, MCFNON, MCFN02, MCFN03, MCFN08, MCFN09, MCFN11, MCFN12, MCFN13, MCINTL, MISABT, MSB011, MSB012, MSB013, MSB021, MSB022, MSB023, MSB041, MSB045, MSB052, MSB111, MSB112, MSB121, MSB122, NAVUPD, NOMINL, PUTALL, READAT, REPAIR, RESULT, RSET12, SETCON, SETST, SUB111, SUB112, UMAINT, USE
MCFLGT	ACQUIRE, ACUPDT, MCARLO, MSB033, MSB111, MSB112
MCOUT	COMBLK, MCARLO, ONE, RESULT, SETCON, SETEVT, SETLAB, SETVAR
MCOUT2	COMBLK, MCARLO, ONE, RESULT, SETCON, SETEVT, SETLAB, SETVAR
MCSYS	ABRT04, ACLOST, ACQUIRE, ACUPDT, COMBLK, DAMAGE, FAPT12, FAIL, FUNCHK, GETMD, MCFAIL, MCFNON, MCFN13, MCINTL, MSB011, MSB012, MSB013, MSB021, MSB022, MSB023, MSB032, MSB033, MSB041, MSB045, MSB101, MSB102, MSB103, MSB104, MSB105, MSB121, MSB122, NEWAC, REPAIR, UMAINT, USE

TABLE B-2. AEP COMMON BLOCKS (Continued)

COMMON BLOCK	ROUTINES USING THE COMMON BLOCK
MDATA	ABRT12, ACLOST, ACQUIRE, COMBLK, FABT07, FABT11, FABT12, FUNCHK, FUNON, FUN12, GETFND, GETMD, MCARLO, MCFN01, MCFN02, MCFN03, MCFN08, MCFN09, MCFN11, MCFN12, MCFN13, MCINTL, MISABT, MSB011, MSB012, MSB013, MSB021, MSB022, MSB023, MSB041, MSB045, MSB052, MSB111, MSB112, MSB121, MSB122, NAVUPD, NOMINL, PUTALL, READAT, REPAIR, RESULT, RSET12, SETCON, SETST, SUB111, SUB112, UMAINT, USE
MTIME	MCINTL, MSB011, MSB012, MSB013, MSB031
NAVERR	ACQUIRE, ACUPDT, MCFN12, MSB071, MSB072, MSB111, MSB112, NAVPOS, NAVUPD
ORDLD	MCFN02, MSB021, MSB022, MSB023, MSB121, MSB122, NEWAC
PROFLE	COMBLK1, CONTRL, FLY, FUNON, NOMINL, READAT, SAVEST
SORTIE	MCARLO, MCINTL, MSB013, MSB021, MSB022, MSB023, MSB041, MSB045, MSB051, MSB052, NEWAC, REPAIR
STADOT	COMBLK1, CONTRL, DERAC, FLY, FUNON, NOMINL, PRTST, SAVEST, SETST
STATES	ACQUIRE, ACUPDT, CLKOFF, CLKON, COMBLK, FABT12, FUNCHK, FUN12, GETMD, MCARLO, MCFN01, MCFN11, MCFN12, MCFN13, MCINTL, MSB011, MSB012, MSB013, MSB031, MSB032, MSB033, MSB045, MSB052, MSB101, MSB102, MSB103, MSB104, MSB105, MSB111, MSB112, MSB121, MSB122, NAVUPD, PRTMC, READAT, RESULT, RSET12, SAVEST, SENSOR, SETCON, SETST, USE
STOPCM	COMBLK, MCARLO, ONE, SETCON

TABLE B-2.AEP COMMON BLOCKS (Continued)

COMMON BLOCKS	ROUTINES USING THE COMMON BLOCK
STRTCM	COMBLK, MCARLO, ONE SETCON
SUBDAT	ABRT12, ACLOST, ACQUIRE, COMBLK, FABT07, FABT11, FABT12, FUNCHK, FUNON, FUN12, GETFND, GETMD, MCARLO, MCFNON, MCFN02, MCFN03, MCFN08, MCFN09, MCFN11, MCFN12, MCFN13, MCINTL, MISABT, MSB011, MSB012, MSB013, MSB021, MSB022, MSB023, MSB041, MSB045, MSB052, MSB111, MSB112, MSB121, MSB122, NAVUPD, NOMINL, PUTALL, READAT, REPAIR, RESULT, RSET12, SETCON, SETST, SUB111, SUB112, UMAINT, USE
SYSDAT	ACUPDT, CLKOFF, COMBLK, DAMAGE, FAIL, MCARLO, MCFAIL, MCINTL, MSB052, NEWAC READAT, REPAIR, RESULT, SETCON, USE
SYSLAB	ONEONE, ONE, READAT
TARGET	ABRT12, ACQUIRE, ACUPDT, COMBLK, FUN12, MCFN11, MCFN12, MCFN13, MSB111, MSB112, READAT, RESULT, RSET13, SETCON
TFAIL	ACLOST, CLKOFF, CLKON, FAIL, MCFAIL, MCINTL, NEWAC, REPAIR, USE
WDELIV	MCFN12, MCFN13, MSB121, MSB122
WDMODE	ABRT12, ACLOST, ACQUIRE, COMBLK, FABT07, FABT11, FABT12, FUNCHK, FUNON, FUN12, GETFND, GETMD, MCARLO, MCFNON, MCFN02, MCFN03, MCFN08, MCFN09, MCFN11, MCFN12, MCFN13, MCINTL, MISABT, MSB011, MSB012, MSB013, MSB021, MSB022, MSB023, MSB041, MSB045, MSB052, MSB111, MSB112, MSB121, MSB122, NAVUPD, NOMINL, PUTALL, READAT, REPAIR, RESULT, RSET12, SETCON, SETST, SUB111, SUB112, UMAINT, USE
WDSUB	ABRT12, ACLOST, ACQUIRE, COMBLK, FABT07, FABT11, FABT12, FUNCHK, FUNON, FUN12, GETFND, MCARLO, MCFNON, MCFN02, MCFN03, MCFN08, MCFN09, MCFN11, MCFN12, MCFN13, MCINTL, MISABT, MSB011, MSB012, MSB013, MSB021, MSB022, MSB023, MSB041, MSB045, MSB052, MSB111, MSB112, MSB121, MSB122, NAVUPD, NOMINL, PUTALL, READAT, REPAIR, RESULT, RSET12, SETCON, SETST, SUB111, SUB112, UMAINT, USE

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